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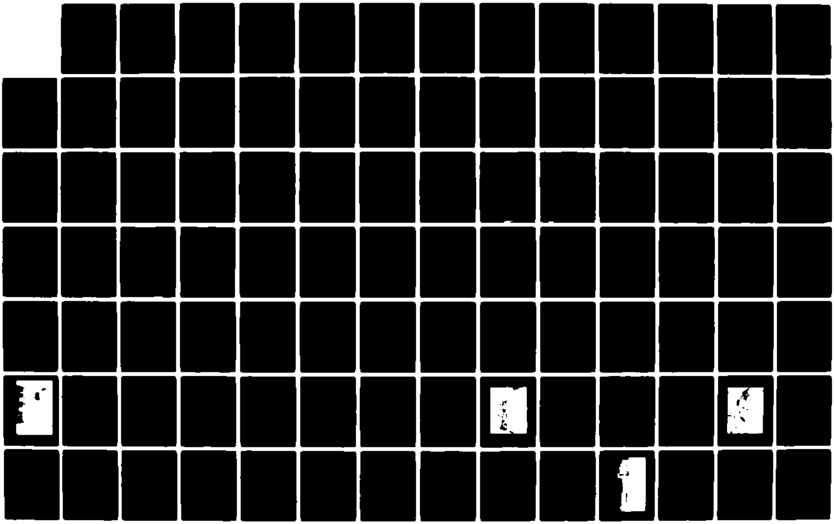

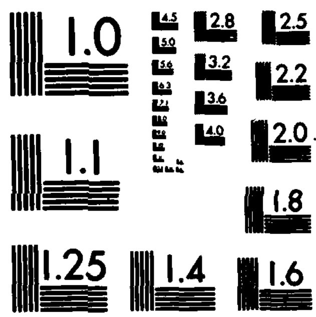

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DOT/FAA/RD-82/62

Systems Research &
Development Service
Washington, D.C. 20591

Instrument Landing System Localizer Vector Far Field Monitor Development

O. A. Baughman
R. A. Rajnic

July 1982

Final Report

This document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161.

U.S. Department of Transportation
Federal Aviation Administration

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NOTICE

Technical Report Documentation Page

1. Report No. DOT/FAA/RD-82/62	2. Government Accession No. AD-A122205	3. Recipient's Catalog No.
4. Title and Subtitle Instrument Landing System Localizer Vector Far Field Monitor Development		5. Report Date July 1982
		6. Performing Organization Code
7. Author(s) O.A. Baughman and R. A. Rajnic		8. Performing Organization Report No.
9. Performing Organization Name and Address Westinghouse Electric Corporation Defense and Electronic Systems Center P.O. Box 1897 Baltimore, Maryland 21203		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. DTFA01-80-C-10134
12. Sponsoring Agency Name and Address Department of Transportation Federal Aviation Administration Systems Research and Development Service Washington, D.C. 20591		13. Type of Report and Period Covered Final Report October 1980 - July 1982
		14. Sponsoring Agency Code FAA/ARD-320
15. Supplementary Notes		

16. Abstract

This Report describes efforts carried out under the contract. It covers design, development and results of testing of the prototype Vector Far Field Monitor (VFFM) equipment. The VFFM is a localizer monitor located in the runway approach area on the runway centerline extended between the threshold and the middle marker vicinity. It measures the in-phase and quadrature components of the scattered and reflected localizer sideband radiation on the localizer course and calculates the potential maximum course DDM disturbance using synchronous and single point detection techniques. Problem of localizer transmitter incidental phase modulation or quadrature modulation effect on the VFFM is dealt with through a provision for a variable adjustment in the VFFM to tune out the corresponding quadrature component of the signal. The report includes a review of VFFM theory, equipment description, including installation and operating instructions, assembly drawings, and circuit schematics, summaries of field test data and recommendations.

17. Key Words ILS, VHF crystal filter, in-phase channel, far field monitor, localizer, incidental phase modulation, quadrature channel, quadrature modulation, synchronous demodulator, static or dynamic signal interference, monitor	18. Distribution Statement Document is available to the public through the National Technical Information Service, Springfield, Va. 22151

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	136	

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METRIC CONVERSION FACTORS

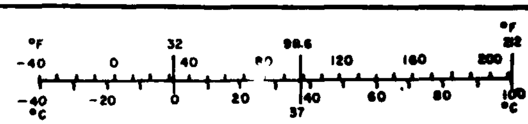
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1.0 INTRODUCTION

1.1 GENERAL

Under the auspices of Request for Proposal No. DTFA01-80-15302, and the ensuing Contract No. DTFA01-80-C-10134 dated 1 October 1980, awarded to Westinghouse Electric Corporation, in Baltimore, Maryland, work began toward the development of an ILS Localizer Far Field Monitor equipment employing the principle of single point vector DDM determination. This report covers the results of the work performed under this contract.

1.2 CONTRACT STATEMENT OF WORK DESCRIPTION

The contractor supplied the personnel, facilities, and equipment necessary to provide the following:

A. Vector Far Field Monitor Feasibility Models

Three feasibility models were designed, fabricated and delivered on 10 May 1982 to the FAA Technical Center in Atlantic City, NJ.

B. Performance Specification

An equipment performance specification pertaining to the developed equipment was prepared and submitted to the contract technical officer in June 1982.

C. Field Test Engineering

Field Test engineering was provided by engineers knowledgeable in the design of the monitors. These services were provided at Baltimore-Washington International Airport and at the FAA Technical Center in Atlantic City, NJ. Westinghouse engineers were responsible for developing and carrying out the test program but received invaluable assistance from local FAA Personnel.

D. Final Report

This document represents the results of the FAA supported work program. Detailed descriptions of each major area of the effort is provided including a review of the monitor theory of operation, a detailed description of the delivered equipment, and a summary of the field test data. Section 6.0 contains conclusions and recommendations necessary for the implementation of this equipment.

1.3 PERIOD OF PERFORMANCE

The original contract called for an 18-month period of performance, however, a six-month extension was requested and granted. This extension was necessary in order to offset time spent in the performance required under a contract modification and in unavoidable delays realized during part of the field testing effort.

2.0 BACKGROUND AND REQUIREMENTS

2.0 INTRODUCTION

Under Contract DOT-FA75WA-3689, Westinghouse performed a study to determine the nature of ILS signal derogation and to develop system concepts for their detection. The resulting report[1] described four monitor concepts. The Vector DDM approach was selected as being the most promising concept for an improved far field monitor. The purpose of Contract DTFA01-80-C-10134 has been to develop hardware from the concepts of the previous contract and to provide field testing demonstrations of its effectiveness.

Although the ILS system provides both azimuthal and elevation guidance, an immediate need exists for accurately monitoring the localizer since its location with respect to the runway subjects its signal to a greater susceptibility to derogation from taxiing and parked aircraft.

2.1 PURPOSE OF THE FAR FIELD MONITOR

The far field monitor is the only device which allows the localizer transmitted signal to be sampled in its operational environment along the critical region of approach in the possible presence of coherent and external interference. The detection and interpretation of such interference is necessary to provide prior warning of potentially critical situations and out of tolerance conditions to incoming aircraft engaged in an ILS approach. Briefly, the far field monitor must detect and evaluate alarm level derogation due to all causes beyond the immediate vicinity of the transmitter. These derogations can be categorized as either dynamic or quasi-static. The former includes perturbations due to overflight and actively taxiing aircraft. The latter includes parked aircraft and changes such as the opening and closing of hangar doors.

It is the presence of quasi-static derogation above specified levels that is most likely to cause unsafe conditions and require alarm. Because quasi-static derogation may be at an unsafe level for significant periods of time, the aircraft guidance instrumentation has sufficient time to respond to the perturbed guidance. An alarm must occur quickly. By contrast, derogation due to fast moving disturbances may considerably exceed specified limits for static derogation and yet be completely safe because of the very brief time period of occurrence. For example, unless a derogation peak exceeds guidance specified limits sufficiently to register on a meter measurement with a 0.4 second time control, it is not considered out of specification on ILS guidance.

Derogations are further categorized as ranging from gradual beam bends to noise. Beam bends can result from reflected or diffracted energy and can have interference envelopes of several thousand feet, whereas noise like interference occurs in regions where reflected energy crosses the approach path close to 90°, and can create interference frequencies as high as 20 to 40 HZ.

2.2 NATURE OF INTERFERENCE CAUSED BY AIRCRAFT OVERFLIGHTS

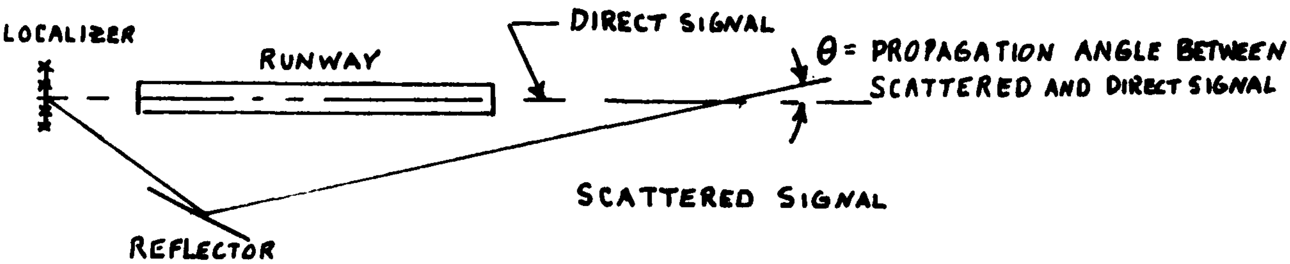
The effects of scattering on ILS localizer monitoring is particularly serious because of the vertical interference patterns which can be generated. Because of their location, (along the runway centerline extended) localizer antennas must maintain a low profile in order to avoid becoming an obstruction. Localizer radiation pattern specifications restrict the vertical radiation pattern at higher angles above the horizontal. Low radiation levels near ground level help to minimize reradiation from aircraft on the ground because they are not highly illuminated; however, aircraft which are taking off or overflying the airport pass through a much greater localizer radiation field. An aircraft taking off and flying over the localizer can cause an overpowering level of derogation to be experienced at a ground based monitor; however, this level of derogation as measured near ground level does not necessarily project to the approach path. A ground-based FFM system should be capable of projecting the actual flight path derogation with reasonable accuracy.

Others[3] have found that the principal source of sustained overflight interference to a localizer far-field monitor comes from aircraft making partial or complete longitudinal passes over or near the centerline of the runway. Previous investigations have revealed that the characteristic frequency and amplitude of this interference is as illustrated in Figure 2-1. The frequency of the interference is the result of the beat between the direct and reflected signals and is symmetrical about a mid-plane between the localizer antenna and the monitor antenna. At this mid-plane, a zero beat occurs. In most instances, the amplitude of the interference is maximum at the zero beat and decreases with an increase in frequency.

2.3 MATHEMATICAL DERIVATION OF VECTOR DDM

The nature of the interaction between a direct and scattered ILS signal that leads to the referendum of Vector DDM can be understood through the following diagrams. Consider first the runway geometry as illustrated below. Since the direct and scattered signal propagate at noncolinear directions, the phase relationship between the direct and scattered signals will vary through the complete 360^{o} circle as the observation point, for example, along the approach path or along a transverse cut, is moved through a sufficient distance.

A vector diagram represents an excellent means for illustrating events when direct and scattered signals are present at an observation point. We can represent the ILS guidance signal as shown in Figure 2-2A. The direct signal consists of a vector representing the CSB and a vector representing the SBO either parallel or antiparallel to the CSB vector, depending upon the location of the scatterer.



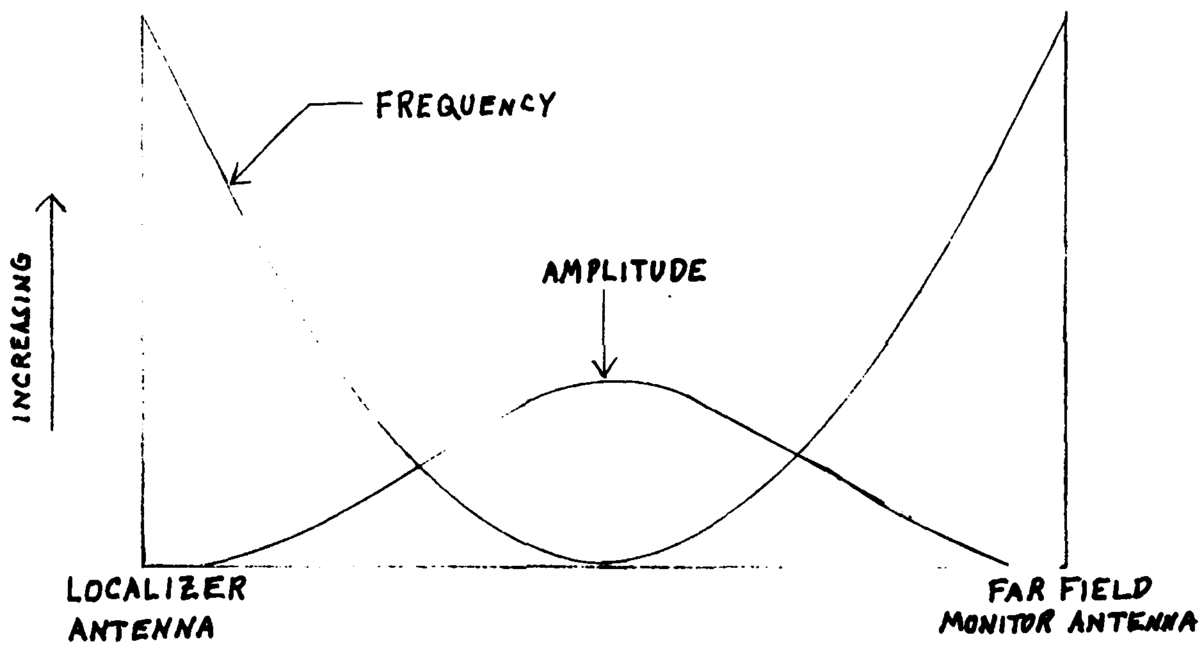


Figure 2-1. Characteristic Frequency-Amplitude Distribution of Overflight Interference to a Localizer Far Field Monitor From a Longitudinal Pass

Because the direct and scattered signals need not have the same CSB - SBO composition, (they will only have the same composition when the scatterer is in a line between the localizer and the point of observation) the composite CSB and SBO vector will not normally be parallel or anti-parallel if significant scattering is present. Note that the composite SBO, in Figure 2-2B, has components both in-phase and quadrature with the composite CSB.

The in-phase component is detected as AM, the quadrature as phase or frequency modulations. It is clear that if the quadrature sum of the AM and PM components is taken, the result is the vector DDM no matter what their relative phases are at the moment of measurement.

It is more significant to show mathematically that the magnitude of the vector DDM so measured is the value of the DDM when the same two signals are phased to give a maximum derogating DDM.

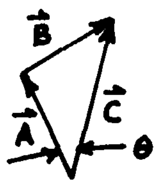
Because of the SBO null which exists along the runway centerline, the direct signal to the monitor is pure CSB.

$$\text{Direct Signal} = \underbrace{\text{SIN } wt}_{\text{carrier}} + (\underbrace{\text{SIN } 300\pi t}_{150\text{ Hz}} + \underbrace{\text{SIN } 180\pi t}_{90\text{ Hz}})m\text{SIN } wt \qquad (2.1)$$

m = modulation index

A scatterer will reflect approximately equal powers in both CSB and SBO. However, the CSB scattered signal will still be very small compared to the direct. Since the SBO on centerline is zero, any scattered SBO will be significant.

In the scattered signal we can therefore neglect the CSB since it produces a minor perturbation to the reference carrier.



$\vec{A}$ = CSB direct

$\vec{B}$ = CSB scattered

$\vec{C}$ = resultant CSB = reference at time of measurement

$\vec{A} \approx \vec{C}$, (θ) is very small

Scattered signal = scattered SBO

$$\text{Scattered signal} = \Big[\underset{150\text{ Hz}}{\text{SIN } 300\pi t} - \underset{90\text{ Hz}}{\text{SIN } 180\pi t}\Big]\alpha\,\text{SIN}(wt + \theta) \qquad (2.2)$$

where α = amplitude of scattered signal

θ = phase of scattered signal, function of path length

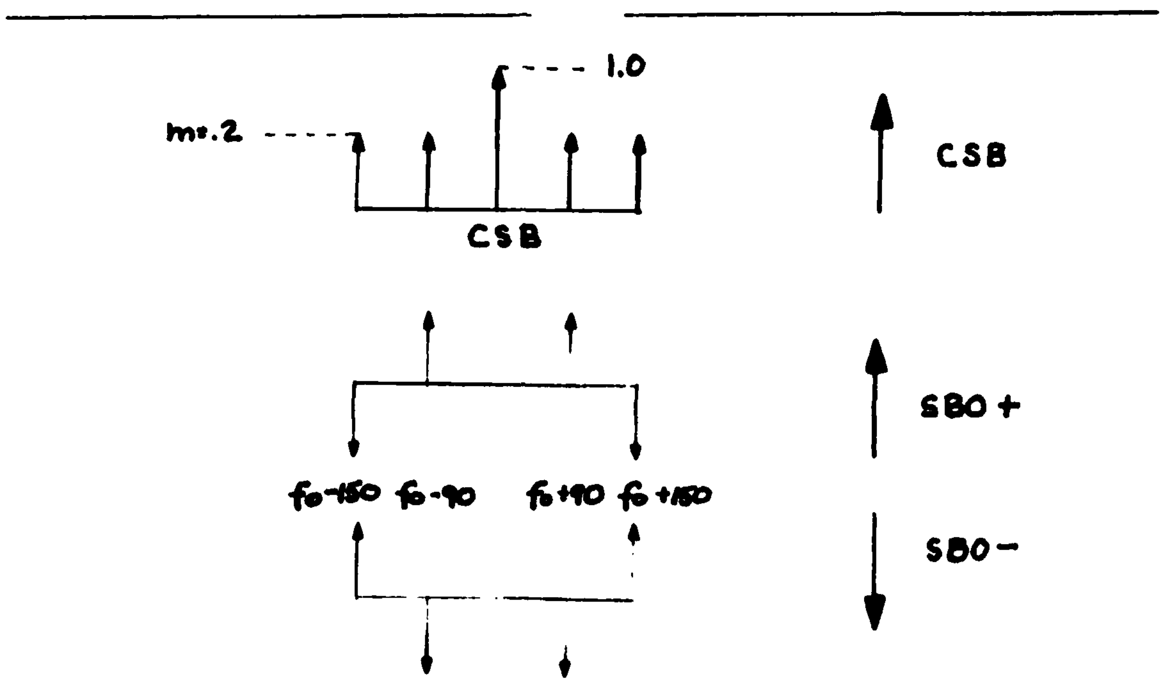


Figure 2-2A. Localizer Signal Format

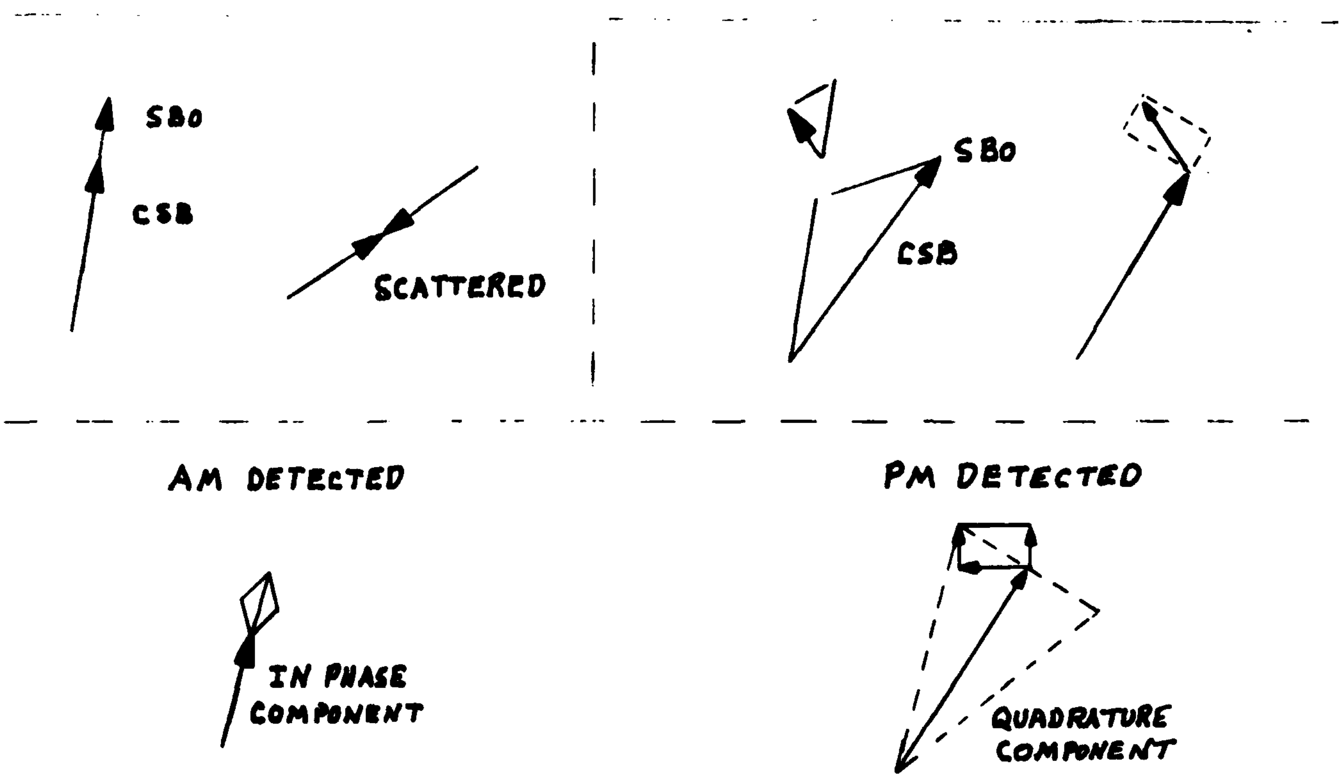


Figure 2-2B. Vector DDM Derogation Detection

We can now define DDM

$$DDM = Re\ \frac{\overrightarrow{SBO}}{\overline{CSB}} = \frac{\overrightarrow{SBO}\ .\ \overrightarrow{CSB}}{|\ \overrightarrow{CSB}\ |^2} = \frac{|\overrightarrow{SBO}|\ \cos\theta}{|\overrightarrow{CSB}|} \qquad (2.3)$$

$$|DDM| \cong \frac{150\text{ Hz total} - 90\text{ Hz total}}{150\text{ Hz total} + 90\text{ Hz total}}$$

Therefore, if 150 Hz total > 90 Hz total, DDM is (+)
150 Hz total < 90 Hz total, DDM is (-)

A typical airport scattering situation and a vector representation of the fields as seen at the far field monitor is shown in Figure 2-3. The scattered SBO produces a variation in DDM (Δ DDM) which has the characteristics of an interference pattern along a line transverse to the extended runway centerline as shown in Figure 2-4. At some point along the glide path, the scattered signal will arrive with its phase angle (Ø) equal to either zero degrees or 180 degrees. In this condition, the maximum glide path distortion will occur since the total SBO scattered signal will contribute to the DDM variation (DDM). Unless the existing FFM antenna was located at the $0 = 0^0$ or 180^0 location, it cannot detect the potential path error which exists since it can only measure:

$$DDM \cong \frac{|SBO|\ \ \cos\theta}{CSB} \qquad (2.4)$$

The vector far field monitor technique measures:

$$DDM \cong \frac{|SBO_{TOT}|}{CSB} \qquad (2.5)$$

$$\text{where } SBO_{TOT} = \sqrt{(SBO\cos\theta)^2 + (SBO\sin\theta)^2} \qquad (2.6)$$

The type of monitor response expected from the existing and from the Vector Far Field Monitor is shown in Figure 2-5. In effect, the VFFM system functions as:

$|CSB|$, measured

$x = |SBO_{TOT}|\cos\theta = |SBO_{TOT}|_{\parallel}$, measured

$y = |SBO_{TOT}|\sin\theta = |SBO_{TOT}|_{\perp}$, measured

$|SBO_{TOT}| = \sqrt{x^2+y^2}$, calculated

Δ DDM (localizer) $\sqrt{\frac{x^2+y^2}{|CSB|}}$, calculated

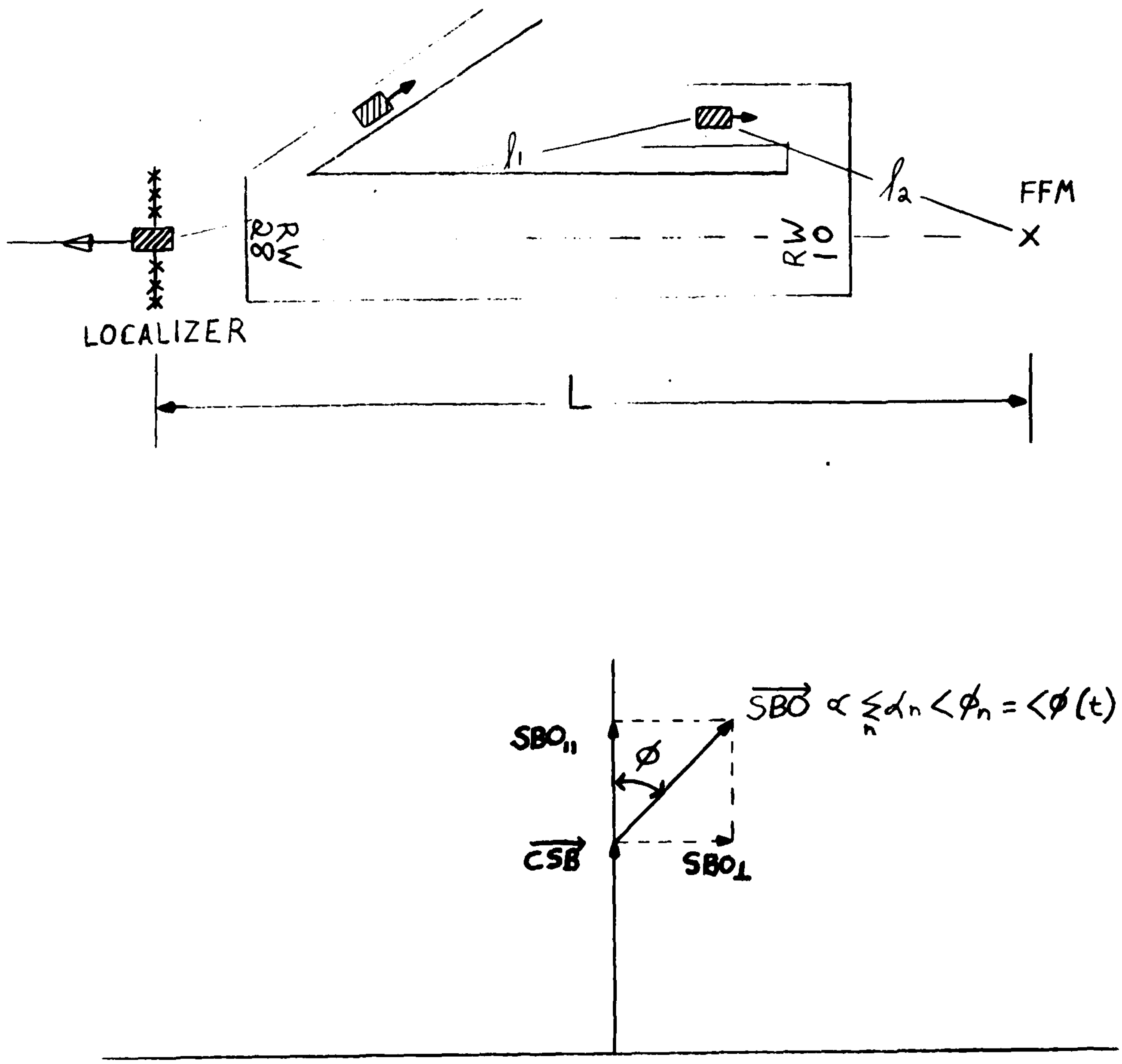


Figure 2-3. Typical Localizer Scatter Diagram and Vector Fields REceived by the FFM

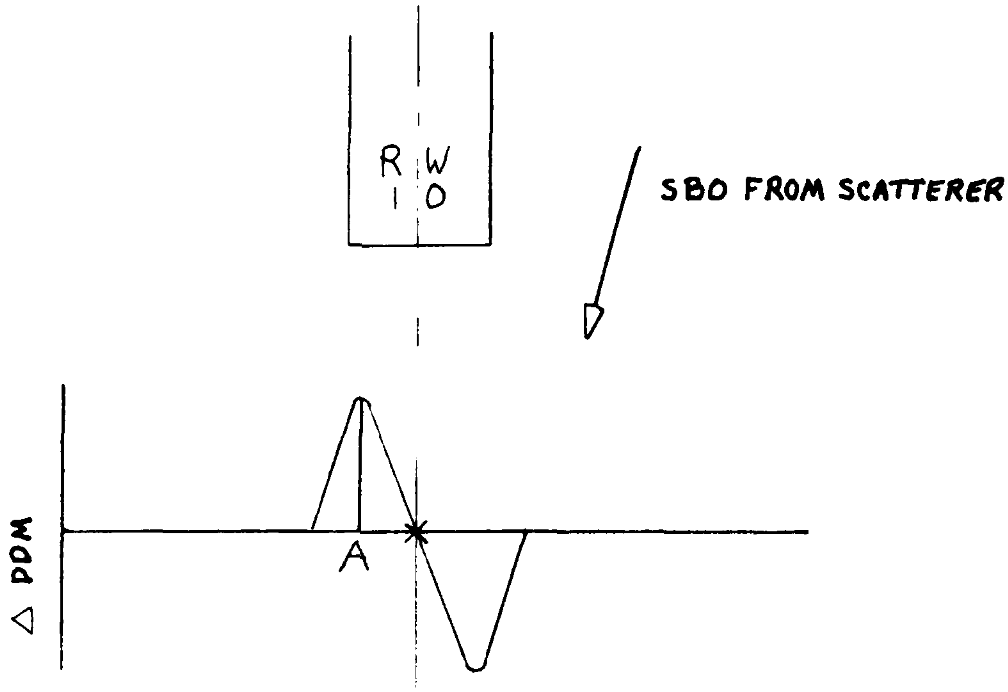


Figure 2-4. DDM Variation Due to Scattered SBO

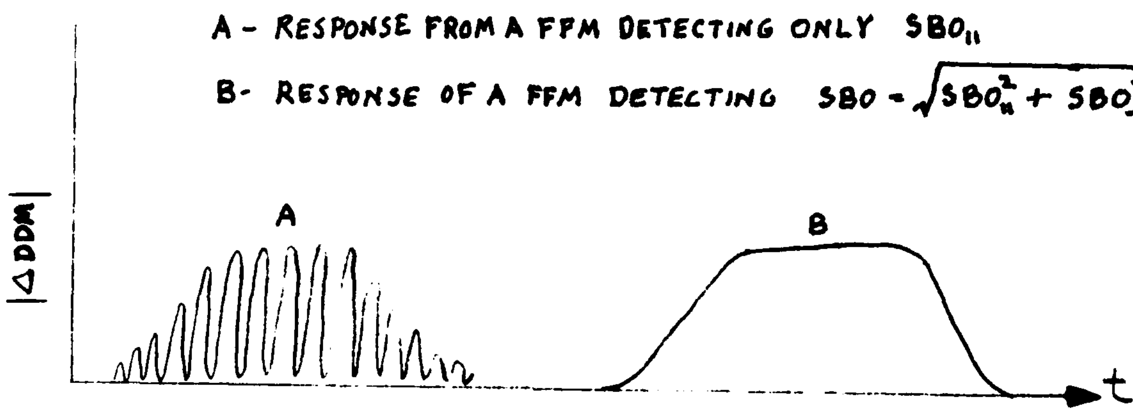


Figure 2-5. Monitor Response

The deficiency of the existing system can be overcome through a multiplicity of probes along a line transverse to the extended centerline. However, the number required to ensure that one probe is located at the derogation peak would reduce reliability and greatly increase cost.

The system described in this report measures both the in-phase and quadrature components of the scattered SBO and constructs the maximum amplitude of the scattered SBO regardless of where this peak occurs relative to the probe.

2.4 SYSTEM ANALYSIS OF VFFM

The functional block diagram of the vector far field monitor is shown on Figure 3-1. Basically, it consists of an RF front end followed by a channel designed to separate and detect the quarature component of the scattered SBO and another channel to detect the in-phase component of the scattered SBO. These are combined in a processor which drives a threshold detector for alarm. The system analysis is given by:

Signal received at the antenna = direct + scattered = S.R.

$$SR=\underbrace{(1+m \sin f_{150}t+m \sin f_{90}t)\sin wt}_{CSB}+\underbrace{\alpha(\sin f_{150}t-\sin f_{90}t)\sin(wt+\theta[t])}_{SBO} \tag{2.7}$$

where m = modulation index

α = amplitude of scattered SBO

$\theta(t)$ = phase of scattered SBO

$$SR=[\sin wt+(\sin f_{150}t+\sin f_{90}t)(m\sin wt)+\alpha(\sin f_{150}t-\sin f_{90}t)\sin(wt+\theta(t))] \tag{2.8}$$

In the quadrature channel, let SR be phase detected using a slow acting PLL with cos wt as the reference:

$$S(quad) = \sin wt \cos wt + (\sin f_{150}t + \sin f_{90}t)m \sin wt \cos wt + \alpha(\sin f_{150}t - \sin f_{90}t) \sin(wt + \theta(t)) \cos wt \tag{2.9}$$

filtering terms in 2 wt:

$\sin wt \cos wt = 0$

$\cos^2 wt = \sin^2 wt = 1/2$

Then:

$$S(quad) = \alpha/2(\sin f_{150}t - \sin f_{90}t) \sin \theta(t) \tag{2.10}$$

Also let SR be phase detected using sin wt as the reference:

$$S(\text{in phase}) = 1/2 + m/2(\sin f_{150}t + \sin f_{90}t) + \alpha/2(\sin f_{150}t - \sin f_{90}t)\cos\theta(t) \quad (2.11)$$

$$S(\text{in phase}) = 1/2 + (m/2 - \alpha/2 \cos\theta(t))\sin f_{90}t + (m/2 + \alpha/2 \cos\theta(t))\sin f_{150}t \quad (2.12)$$

Separating those components with filtering and taking the absolute value:

$$S(\text{quad})_{90} = \frac{\alpha}{\pi}\sin\theta(t) \quad (2.13)$$

$$S(\text{quad})_{150} = \frac{\alpha}{\pi}\sin\theta(t) \quad (2.14)$$

$$S(\text{in-phase})_{90} = \frac{1}{\pi}(m - \alpha\cos\theta(t)) \quad (2.15)$$

$$S(\text{in-phase})_{150} = \frac{1}{\pi}(m + \alpha\cos\theta(t)) \quad (2.16)$$

These signals are passed through low pass filters with w_c (cutoff freq.) chosen to limit accepted target velocity.

The processor forms the following combinations:

$$S(\text{in phase})_{150} - S(\text{in phase})_{90} = 2\alpha/\pi \cos\theta \equiv |SBO_{TOT}|_{\parallel} \quad (2.17)$$

$$S(\text{in phase})_{150} - S(\text{in phase})_{90} = 2m/\pi \equiv |CSB| \quad (2.18)$$

$$S(\text{quad})_{150} + S(\text{quad})_{90} = 2\alpha/\pi \sin\theta \quad |SBO_{TOT}|_{\perp} \quad (2.19)$$

$$\sqrt{|SBO^2_{TOT}| + |SBO_{TOT}{}^2|} = 2\alpha/\pi \equiv |SBO_{TOT}| \quad (2.20)$$

This goes to a threshold detector for alarm.

The DDM is calculated:

$$\frac{|SBO|_{TOT}}{|CSB|} = \frac{\alpha}{m} = |DDM| \quad (2.21)$$

A comparitor examines the sign of SBO to determine the modulation sense of |DDM|.

convention; + (150 Hz), - (90 Hz).

The SDM is calculated from this relationship.

$$S(\text{in phase})_{150} + S(\text{in phase})_{90} = 2m/\pi \quad (2.22)$$

The implementation into hardware form of this system analysis is described in Section 3.

3.0 VECTOR FAR FIELD MONITOR EQUIPMENT DESCRIPTION

This section describes in detail the equipment which was designed and developed under contract DTFA01-80-C-10134. This includes a functional description of equipment operation, detailed circuit description, assembly drawings, schematic diagrams, and equipment operation procedures.

3.1 DESIGN GOALS

In general, the equipment design was consistent with the system approach described in the VFFM technical proposal[5]. Where possible an attempt was made to select off-the-shelf circuit modules which met the requirements of the functional modules. Specific performance parameters which were designed to and achieved included:

Temperature Requirement: Environment II (-10°C to +50°C).

Construction: Chassis mounted modules for 19 inch rack or cabinet mounting.

RF Input Impedance: The RF input of the receiver is matched to 50 ohms (nominal) unbalanced transmission line with a VSWR of 1.3:1 maximum.

RF Sensitivity: The equipment can operate over an RF input voltage range of two microvolts (-101 dBm) to 10 millivolts (-27 dBm).

Signal to Noise Ratio: The noise level in the receiver output signal must be at least 20 dB below the output signal-plus-noise level.

Primary Power: 120 VAC 1 Phase, 60 Hz.

Desensitization: For a desired input signal of five microvolts modulated 30 percent at 150 Hz, a four-volt signal at ±4 MHz from the desired signal must cause a loss of gain of no more than two dB.

Selectivity: Performance requirements must be met over the following ranges from the assigned channel frequency:

- 10 KHz minimum at -6 dB points
- 35 KHz maximum at -60 dB points
- 60 KHz maximum at -90 dB points

Image and IF Rejection: The image and IF rejection must be at a minimum of 90 dB below the carrier level.

Cross Modulation: For a desired input signal of five microvolts, an unwanted signal at 60 dB ± 50 KHz away modulated at 50 percent will cause a maximum of 10 percent distortion.

Frequency Response: The audio output amplitudes must be within ±0.1 dB of each other over a 3 KHz bandwidth for equally 20 percent modulated 90 Hz and 150 Hz tones.

Percent Modulation: The AC output must vary linearly from zero to 60 percent modulation. The DC output must not change appreciably as the percent of modulation is varied.

Audio Output: For a 20 microvolt input signal, 20 percent modulated at 90 Hz, the output must be adjustable from 0 to at least 125 percent of the minimum required for the monitor input.

Synchronous Demodulation: Synchronous demodulation techniques must be employed to detect the in-phase and quadrature components of the direct CSB and scattered SBO ILS signals received. Sufficient isolation must exist between the in-phase and quadrature channels.

AGC Characteristics: The receiver must have essentially flat AGC characteristics. The value of the carrier voltage at the input of the detector stage must be maintained constant within ± 1 dB for input signal variations from 5 to 10,000 microvolts.

Spurious Response: All spurious responses, including responses to image frequencies, must be such that the input signal required to lock up the receiver at any specific frequency shall be at least 60 dB stronger than that required to lock up the receiver at 108-112 MHz.

Monitor Performance: The monitor channel signal processing circuits must determine the magnitude of the DDM resulting from both in-phase and quadrature components of the scattered SBO output.

3.2 FUNCTIONAL SYSTEM DESCRIPTION/THEORY OF OPERATION

The VFFM consists of a superheterodyne receiver group for reception, demodulation, and detection of localizer signals and a monitor group to provide processing and fault detection of the detected audio signals from the receiver. The receiver group consists of four functional modules:

A2 - RF amplifier/local oscillator
A3 - 10.7 MHz IF amplifier
A4 - Synchronous Demodulator
A5 - Voltage controlled crystal oscillator

These modules serve to convert the localizer RF input signal to an audio DC output for input to the monitor channel. The monitor group consists of the following functional modules:

A1 - Signal processor
A6 - Special signal processor for Q-channel adjustment

A functional block diagram of the VFFM system is shown in Figure 3-1. Each of the receiver group modules are contained in RF shielded enclosures with interface provided by semirigid coax with SMA connectors. Access to the printed circuit boards within the enclosures is provided without removing the modules from the chassis. The monitor modules consist of double sided printed circuit boards which are directly connected to the chassis with standoffs.

3.2.1 RF CONVERSION

The localizer input signal (108-112 MHz) is converted to a 10.7 MHz IF frequency in order to provide low spurious conversion. This standard frequency provides a wide selection of standard IF filter components. Suppression of adjacent channel interference is provided by using RF and mixer sections with a wide dynamic range and by preselection.

3.2.2 IF AMPLIFICATION AND SYNCHRONOUS DEMODULATION

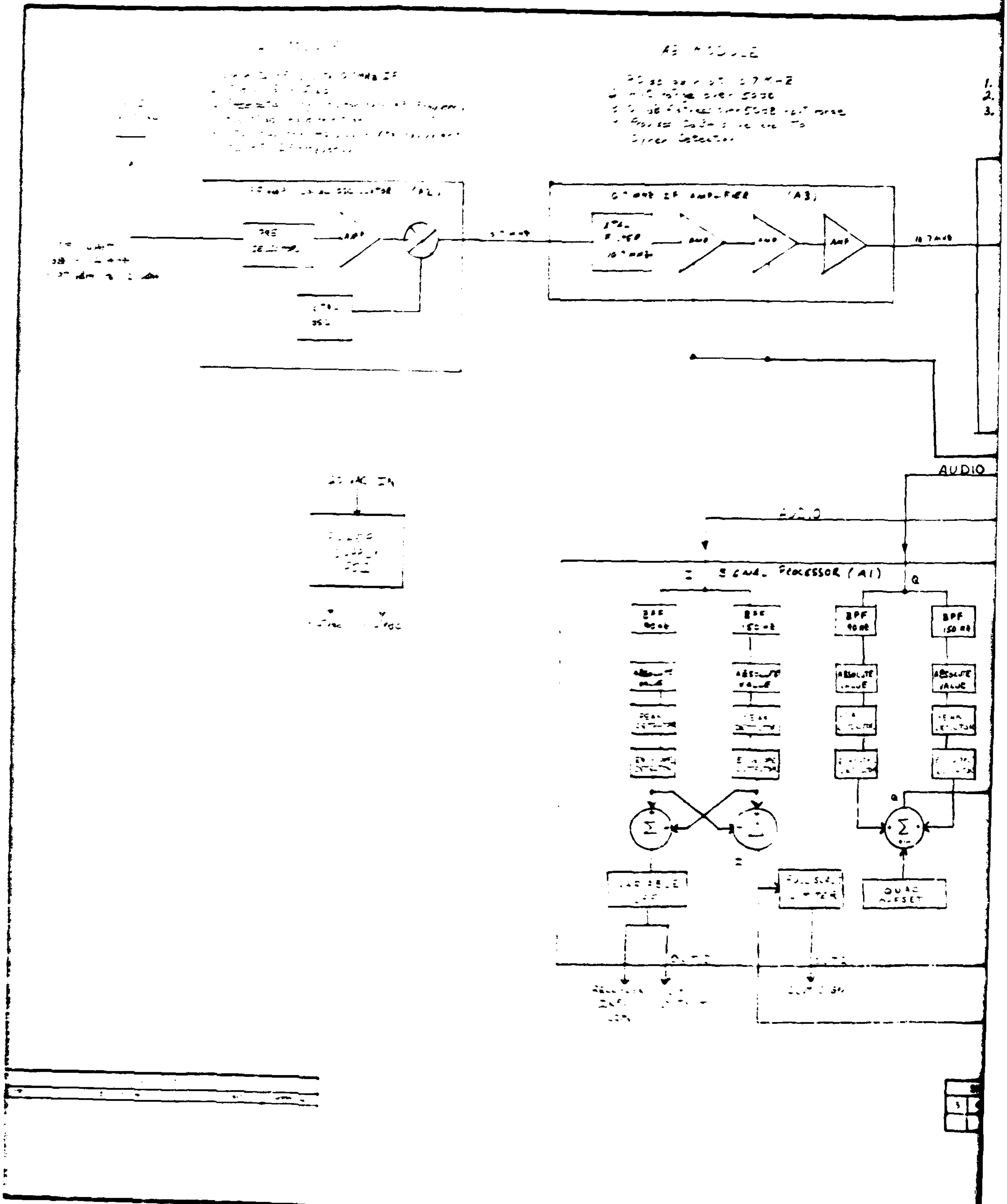
IF amplification is provided to supply sufficient gain to meet the two microvolt input signal requirement.

In-phase and quadrature synchronous detection allows the scattered signal (SBO) to be isolated from the direct signal (CSB) by means of processing at base band. The in-phase channel provides detection of the direct signal and also the in-phase component of the scattered signal. The quadrature channel provides rejection of the direct signal but responds to the quadrature component of the scattered signal. A block diagram of the synchronous demodualtion hardware is shown in Figure 3-1. A slow acting PLL locks the VCXO in quadrature with the output of a limiting amplifier. The output consists of a carrier with phase modulation components at 90 Hz, 150 Hz, and at harmonics of these frequencies. A slow acting PLL loop locks the VCXO in quadrature with the carrier component without tracking the phase modulation which is primarily the result of scattered signals. The phase modulation error signals at the mixer output port, therefore, remain large and are directly applied to the processor quadrature channel input.

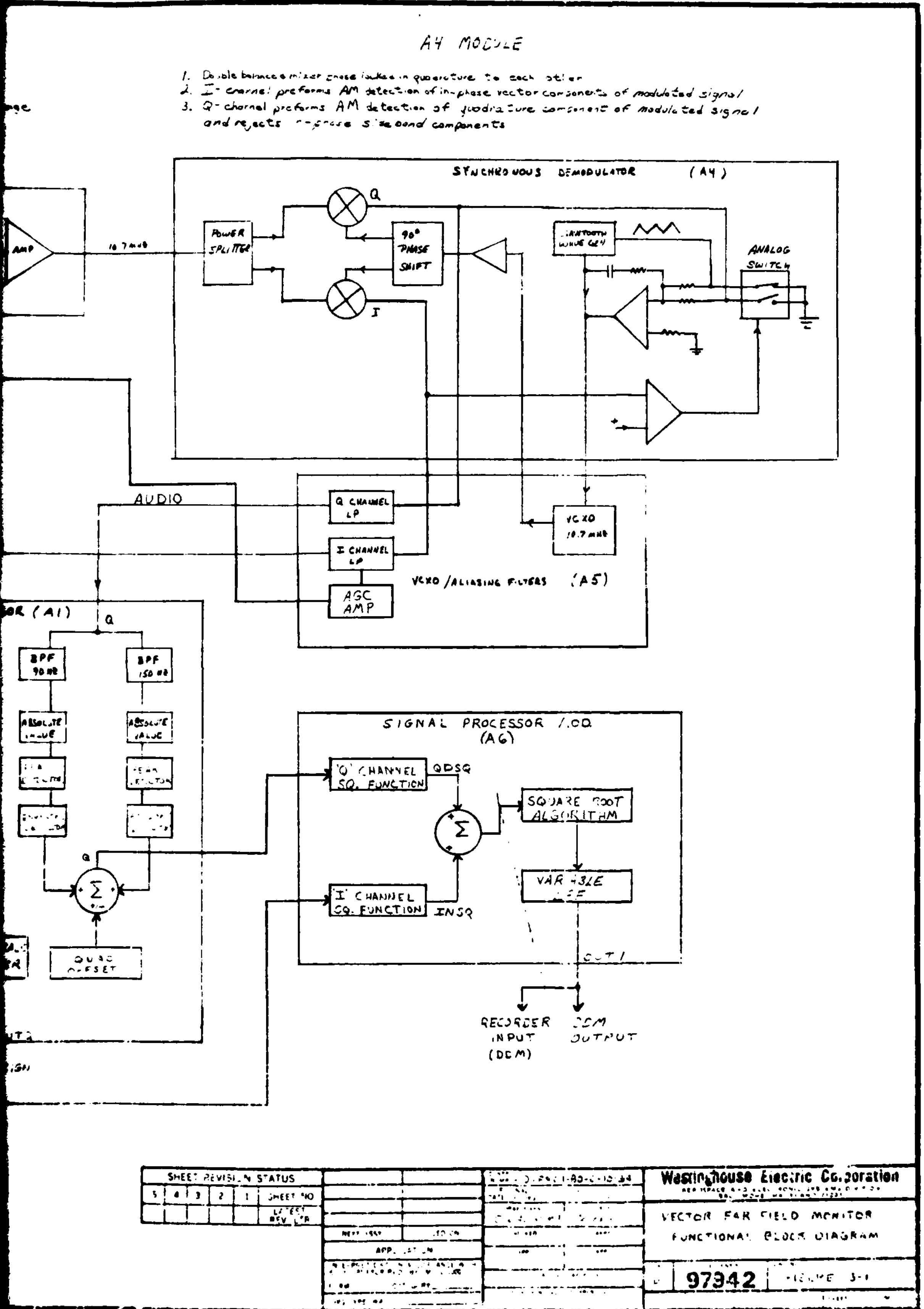
The in-phase mixer output contains a DC component proportional to the carrier strength of the direct signal, modulation components of the signal which are equal at the center of the localizer beam, and scattered signals which are phase dependent. The scattered signals in the two channels have phase dependence that is in quadrature. This allows the magnitude of the scattered signal to be extracted by processing.

3.2.3 SIGNAL PROCESSING

The signal processor performs three major functions: (1) it provides Q-channel compensation for localizer transmitter incidental phase modulation; (2) it regulates the modulation sideband levels in the processor by control of the IF amplifier gain; and (3) extracts the magnitude of the scattered signal and outputs the results to the panel meters and chart recorder output. The I&Q inputs to the signal processor (A1) module contain 90 Hz and 150 Hz components which are separated by digital filters, which are designed



A3 MODULE
AMP
PRE SELECTOR
XTAL OSC
XTAL FILTER 10.7 MHz
AMP
AMP
AMP
10.7 MHz
AUDIO
SIGNAL PROCESSOR (A1)
Q
BPF 90 HZ
BPF 150 HZ
BPF 90 HZ
BPF 150 HZ
ABSOLUTE VALUE
ABSOLUTE VALUE
ABSOLUTE VALUE
ABSOLUTE VALUE
PEAK DETECTOR
PEAK DETECTOR
QUAD OFFSET
1.
2.
3.


A4 MODULE
1. Double balance mixer phase locked in quadrature to each other
2. I-channel preforms AM detection of in-phase vector components of modulated signal
3. Q-channel preforms AM detection of quadrature component of modulated signal and rejects in-phase sideband components
SYNCHRONOUS DEMODULATOR (A4)
AMP
10.7 MHz
POWER SPLITTER
Q
I
90° PHASE SHIFT
SAWTOOTH WAVE GEN
ANALOG SWITCH
AUDIO
Q CHANNEL LP
I CHANNEL LP
AGC AMP
VCXO 10.7 MHz
VCXO /ALIASING FILTERS (A5)
OR (A1)
Q
BPF 90 HZ
BPF 150 HZ
ABSOLUTE VALUE
ABSOLUTE VALUE
SIGNAL PROCESSOR /DDM (A6)
'Q' CHANNEL SQ. FUNCTION
QDSQ
'I' CHANNEL SQ. FUNCTION
INSQ
SQUARE ROOT ALGORITHM
VARIABLE
Σ
QUAD OFFSET
OUT 1
RECORDER INPUT (DDM)
DDM OUTPUT
SHEET REVISION STATUS
5 4 3 2 1 SHEET NO
LATEST REV. LTR
APPLICATION
Westinghouse Electric Corporation
VECTOR FAR FIELD MONITOR
FUNCTIONAL BLOCK DIAGRAM
97942
FIGURE 3-1

to provide greater than 30 dB isolation. After filtering the modulation frequencies are detected with peak and envelope detectors. The sum and differences of the detected modulations are formed in the in-phase channel. The sum term of the in-phase channel represents the SDM level. The quadrature channel is similar to the in-phase channel except that only its sum term is computed. The sum term of the Q-channel is combined vectorially with the difference term from the I-channel to form the magnitude of the scattered signal, independent of reflection phase. These two components are then formulated in the square root of the sum of the squares ($\sqrt{I^2+Q^2}$) to produce the magnitude of DDM which is ultimately displayed.

3.3 RESERVED

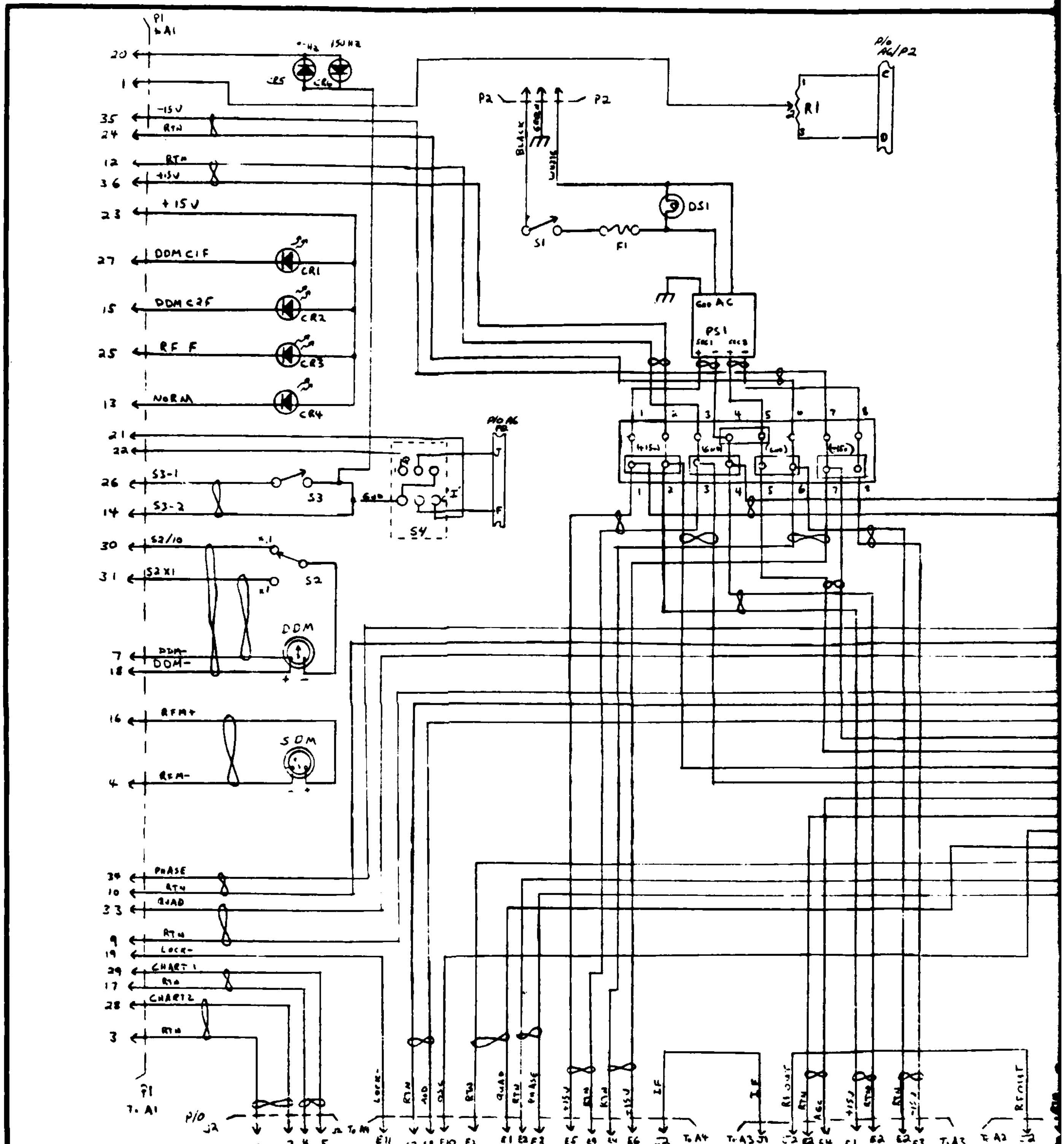
3.4 DETAILED EQUIPMENT DESCRIPTION

Three prototype VFFM units (S/N 001, 002 and 003) were designed, built, and delivered under this program. The unit consists of a chassis mounted receiver and monitor group which was slide-mounted inside an equipment cabinet. The overall dimension of the unit is 17 inches x 19 inches x 9 inches. The equipment was designed for field testing purposes only. An operational far field monitor system would also include an auxiliary power source, AC/DC converters, and combination circuitry to interface with a remote indicator/control unit. The equipment can be used with the four-element MX-9026/GRN-27 yagi antenna and has been successfully used with the PIR half-wave dipole antenna. In addition to the antenna feed, the only item required for equipment operation is a 120 VAC 1 Phase 60 Hz power source. The VFFM is an all solid-state single channel monitor used to evaluate the localizer course (CSB) signal for equal amplitudes (0 DDM) to ensure proper guidance signal tolerances within prescribed limits.

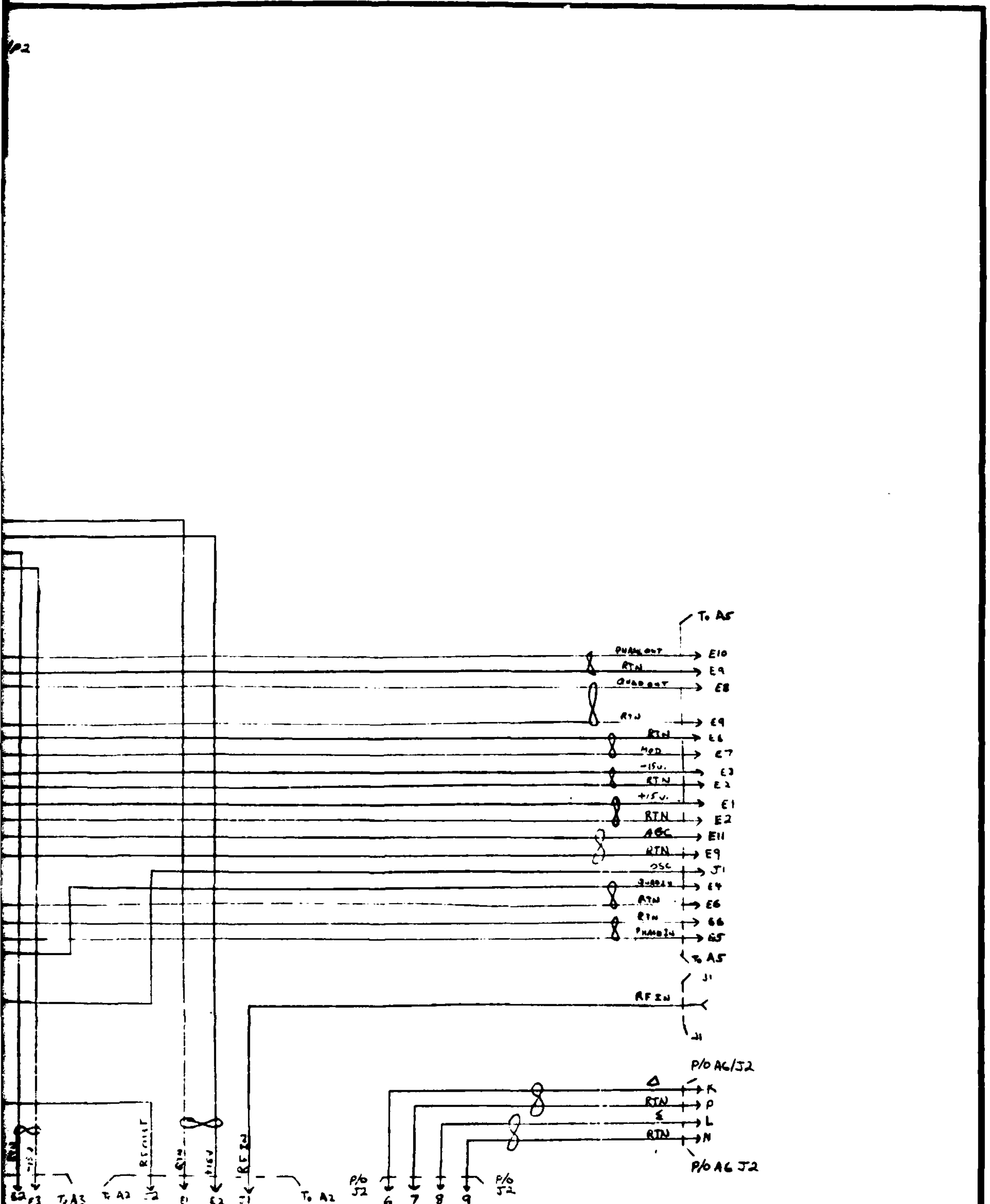
3.4.1 RF AMPLIFIER/LOCAL OSCILLATOR (A2) MODULE

The schematic diagram for this module is shown in Figure 3-3. This unit consists of a narrow band crystal preselector, a low noise RF amplifer, a double balanced mixer and stable crystal controlled local oscillator. The circuitry is mounted on a 2.65 x 4.70 inch double-sided printed circuit board. The RF preselector is a two-crystal, half lattice design which provides a smooth frequency response across the desired inband range and very high rejection to out-of-band signals. The attenuation at the image frequency is greater than 90 dB. This filter is a plug-in 2-1/2 x 1 x 1/2 inch module. The input and output impedance of this filter is 50 ohms.

The preselector is followed by a low noise Watkins Johnson broadband RF amplifier. This amplifier provides 13 dB of RF gain and has a noise figure of less than 5.5 dB over the desired 108 MHz to 112 MHz frequency range. This unit is a wide dynamic range, linear amplifier providing a third order intercept point of +39 dBM and is therefore, capable of handling the maximum inband signals without requiring a voltage variable attenuator preceeding this amplifier.



REVISIONS			
LTR	DESCRIPTION	DATE	APPROVAL

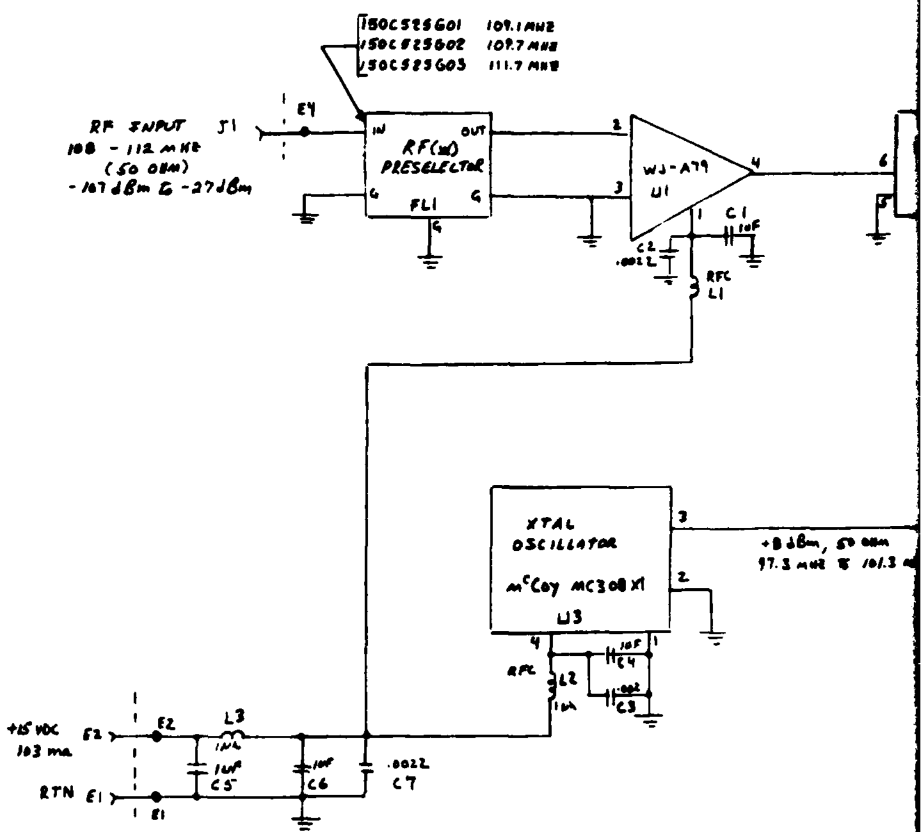


Westinghouse Electric Corporation

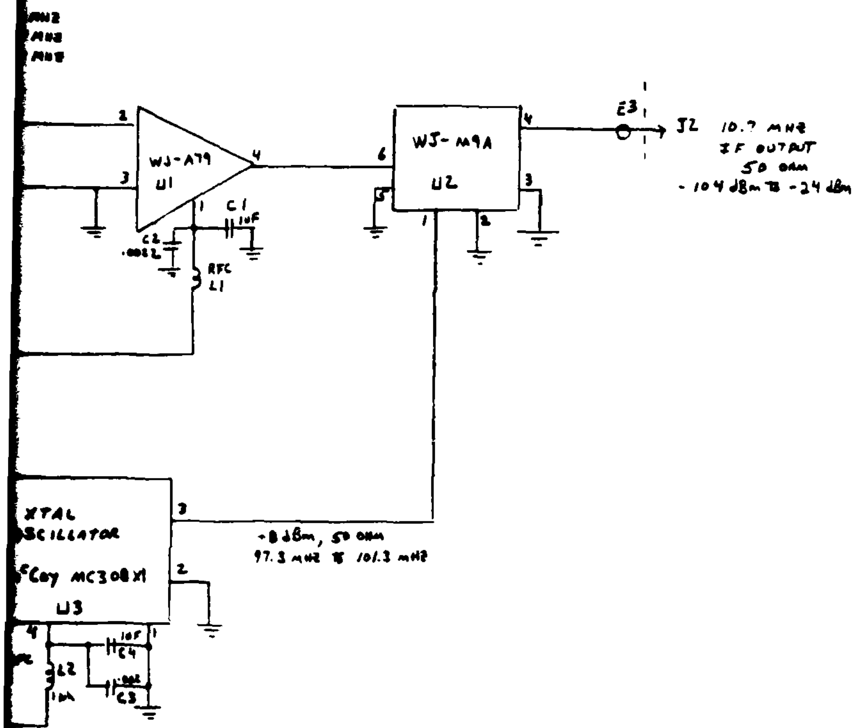
VECTOR FAR FIELD MONITOR
CHASSIS WIRING DIAGRAM

D 97942 FIGURE 3-2

2



REVISIONS			
LTR	DESCRIPTION	DATE	APPROVAL



SHEET REVISION STATUS					
5	4	3	2	1	SHEET NO
					LATEST REV. LTR

NEXT ASSY | USED ON

APPLICATION

INTERPRET DWG IN ACCORDANCE WITH STDS PRESCRIBED BY MIL-D-1000

FORM CATEGORY

DWG TYPE

CONTRACT NUMBER DTFA01-83-C-10134

ORIGINAL DATE OF DWG 12-17-83

DRAFTSMAN

CHECKED

DESIGN ACTIVITY APPROVAL

Westinghouse Electric Corporation

AEROSPACE AND ELECTRONIC SYSTEMS DIVISION BALTIMORE, MARYLAND

RF AMPLIFIER / LOCAL OSCILLATOR SCHEMATIC DIAGRAM A2 MODULE

SIZE D | CODE IDENT NO 97942 | FIGURE 3-3

SHEET OF

2

The RF amplifier is followed by a high level Watkins Johnson M9A, double-balanced mixer. This mixer converts the RF signal to a 10.7 MHz IF signal. The local oscillator injection to this mixer is provided by a model MC308X1 McCoy crystal oscillator. The amplifier/oscillator circuit board requires +15 VDC at 90 ma nominal current drain. The PC board layout drawing is shown in Figure 3-9.

3.4.1.1 DESCRIPTION OF RF PRESELECTOR

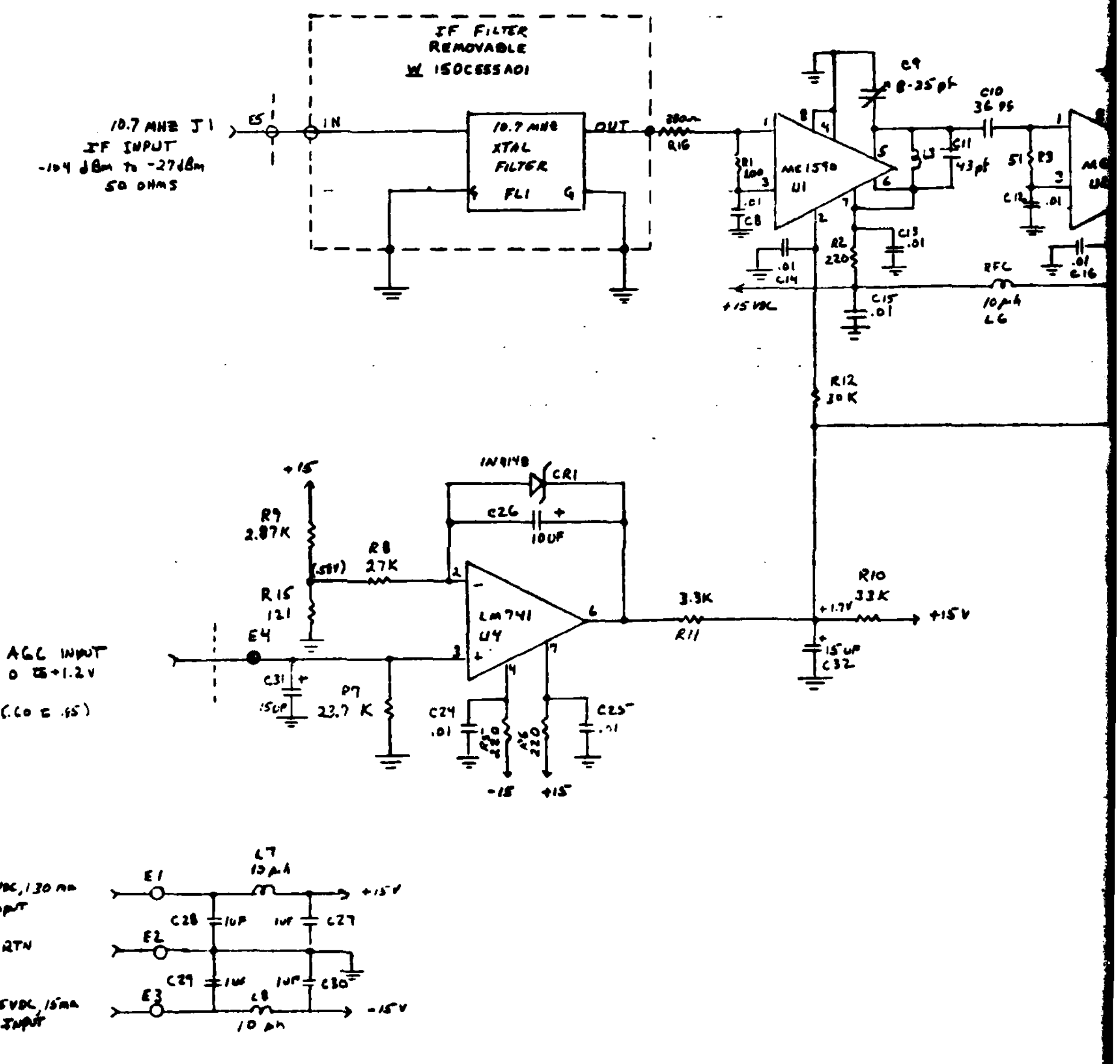
The frequency of operation within the localizer band is determined by the crystal in the local oscillator and the frequency of the preselector filter. The operating frequency of VFFM S/N 001 is 109.70475 MHz and for S/Ns 002 and 003, it is 109.10475 MHz. The preselectors are nontuneable and were designed for the specific test frequencies of the localizer systems interfaced with during the performance of the contract.

The constraints which were faced in the approach to this filter design were that it should have low insertion loss, reject the image at twice the IF by 90 dB, yield 40 dB at ±4 MHz and be compact. At this frequency, the latter two requirements dictated a quartz crystal resonator filter because other high Q-resonators (L-C, cavity, helical) are very large. Such a design would have met the first two requirements, but the drawback was that conventional designs suffer from the effects of large close-in spurious responses in overtone quartz crystal resonators. These damage the response in two ways: first, because these spurious responses always occur above the desired resonance of the crystal and the conventional frequency of this resonance is below the passband, then the latter is ruined by very sharp ripples or "snivets"; second, these spurious continue to occur out into the stopband and ruin the upper skirts by creating big holes in the desired response. The first effect would defeat the purpose of VFFM by introducing errors in the relative level of the sidebands and the second would have prevented the filter from rejecting stopband frequencies if they fell into one of the spurious "holes".

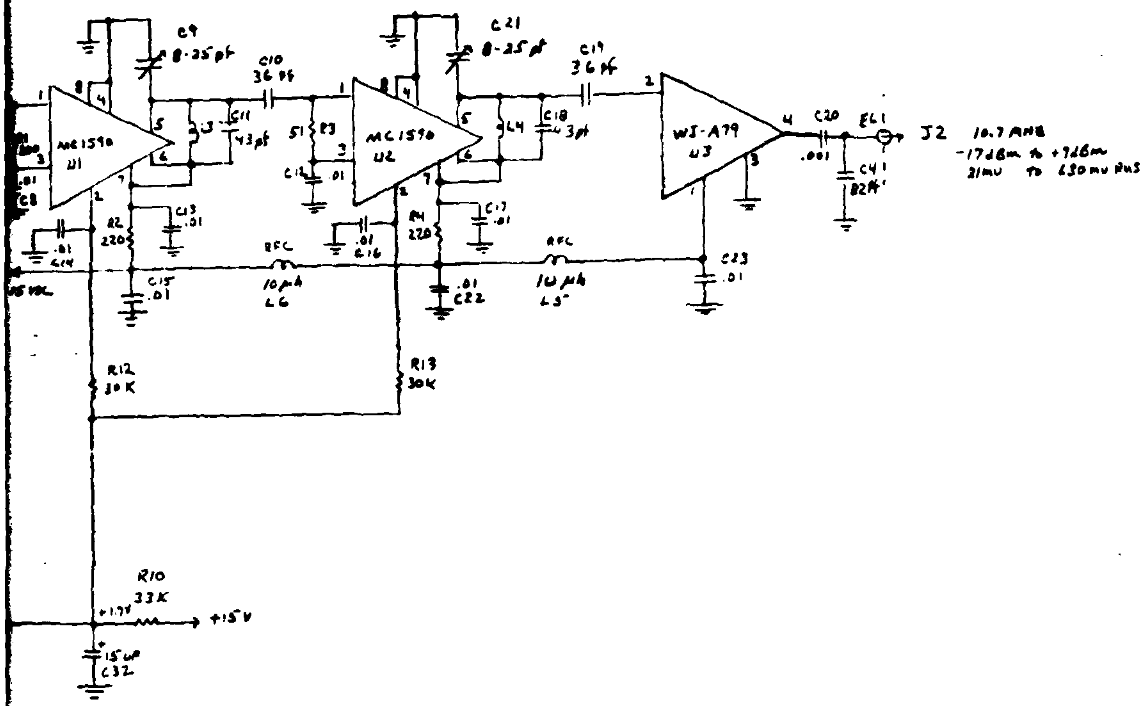
To satisfy the requirements of the VFFM system, a unique filter was developed for which Westinghouse has applied for patent. It is a design which negates both of the bad effects of crystal spurious responses. Simply put, it is a filter realized as a cascade of as many single crystal half-lattices as there are desired poles in the filter. Thus, a three-pole filter would be realized as a cascade of three half-lattices each having a single crystal in one of its arms. Further, the half-lattices are so coupled that the crystal frequency is above the passband, not below it. The benefits of this configuration are:

1. There are no spurious-caused ripples in the passband.

2. What spurious are present are located further down the upper skirt of the filter thus causing less disturbance of the stopband.



REVISIONS			
LTR	DESCRIPTION	DATE	APPROVAL



REVISIONS

L1, L2 REMOVED
C1, C2, C3, C5, C6, C7 REMOVED
R14 REMOVED
R16 ADDED
R1 Was: 200Ω Now: 100Ω

SHEET REVISION STATUS					
5	4	3	2	1	SHEET NO
					LATEST REV LTR

NEXT ASSY | USED ON

APPLICATION

INTERPRET DWG IN ACCORDANCE WITH STDS PRESCRIBED BY MIL-D-1000

FORM | CATEGORY

CONTRACT NUMBER DTFA01-80-C-10134

DATE OF DWG

DRAFTSMAN C. CHURCHMAN

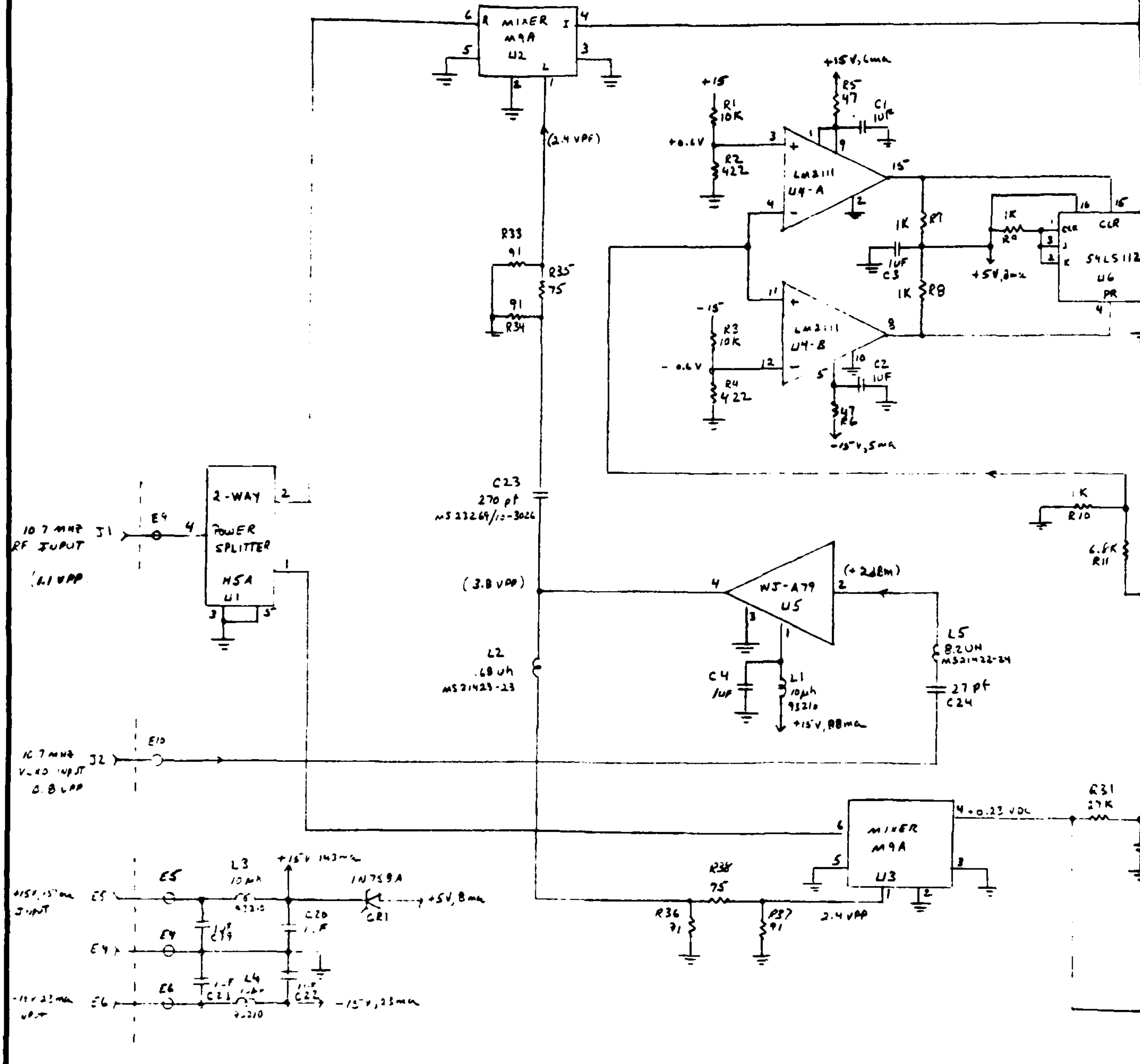
CHECKED

APPD

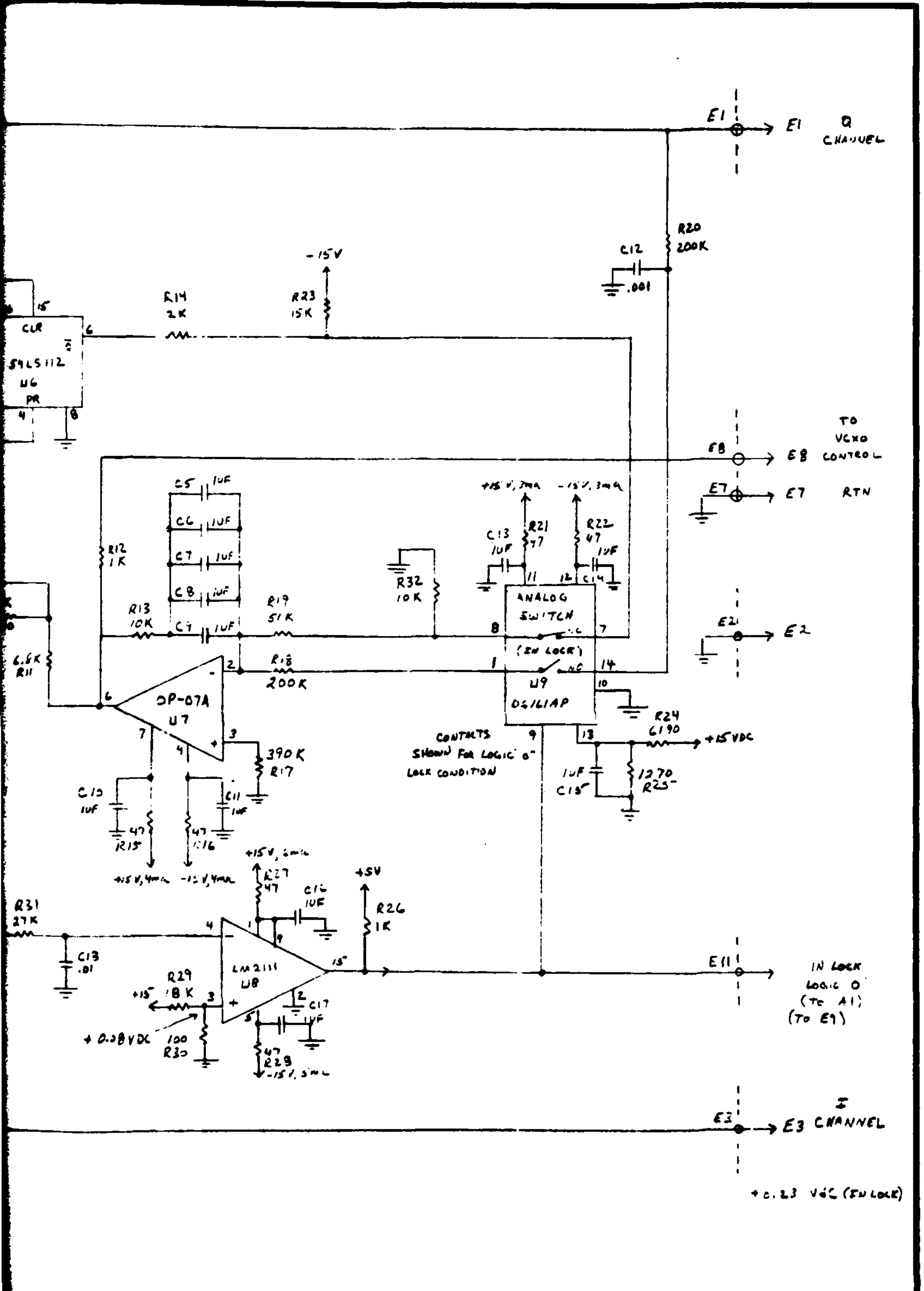
Westinghouse Electric Corporation
AEROSPACE AND ELECTRONIC SYSTEMS DIVISION
BALTIMORE, MARYLAND

10.7MHz IF/AGC AMPLIFIER
SCHEMATIC DIAGRAM
A3 MODULE

SIZE D | 97942 | FIGURE 3-4



REVISIONS			
LTR	DESCRIPTION	DATE	APPROVAL



SHEET REVISION STATUS					
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					LATEST REV. LTR

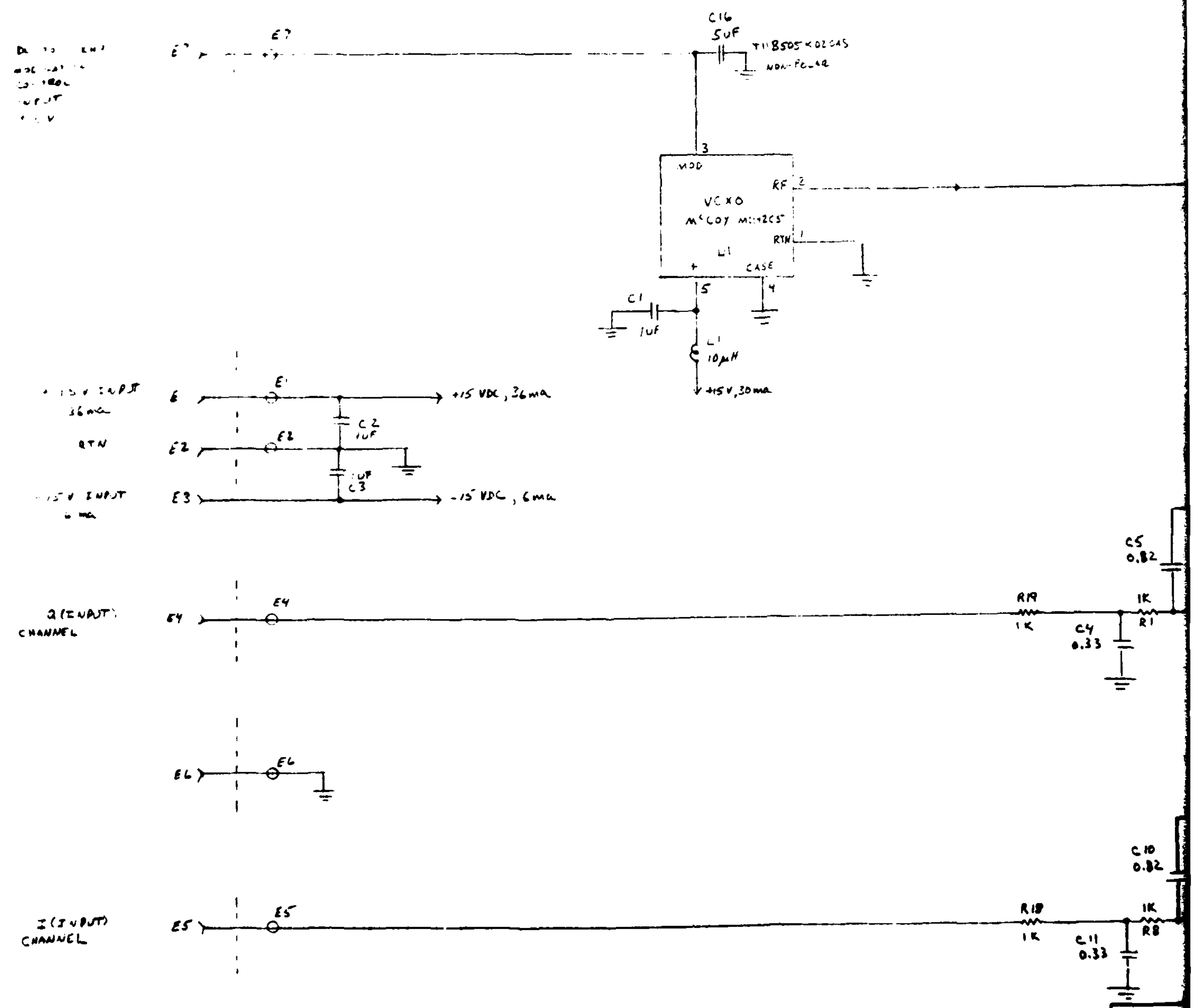
NEXT ASSY	USED ON
APPLICATION	
INTERPRET DWG. IN ACCORDANCE WITH STDS. PRESCRIBED BY MIL-D-1000	
FORM	CATEGORY

CONTRACT NUMBER DT F...-30-C-10134
ORIGINAL DATE OF DWG ...-7-81
DRAFTSMAN D. ...
CHECKED
APPD

Westinghouse Electric Corporation
AEROSPACE AND ELECTRONIC SYSTEMS DIVISION
BALTIMORE, MARYLAND

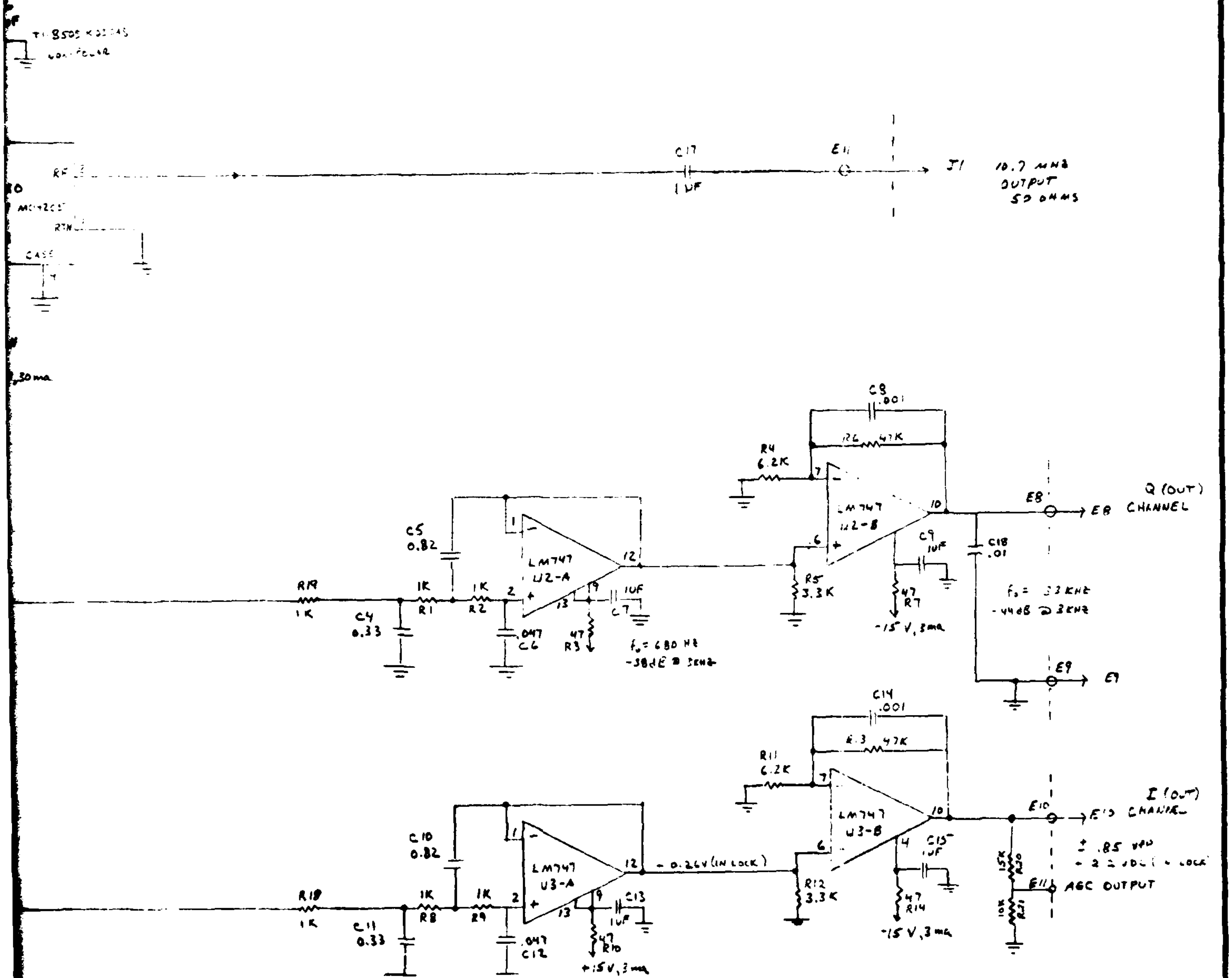
SYNCHRONOUS DEMODULATOR
SCHEMATIC DIAGRAM
A4 MODULE

97942 FIGURE 3-5



REVISIONS			
LTR	DESCRIPTION	DATE	APPROVAL

SHEET		
5	4	3



SHEET REVISION STATUS					
5	4	3	2	1	SHEET NO
					LATEST REV LTR

NEXT ASSY | USED ON

APPLICATION

INTERPRET DWG IN ACCORDANCE WITH STDS PRESCRIBED BY MIL-D-1000

FORM CATEGORY

DWG TYPE

CONTRACT NUMBER

DATE OF DWG

DRAFTSMAN | APPD

CHECKED | APPD

Westinghouse Electric Corporation

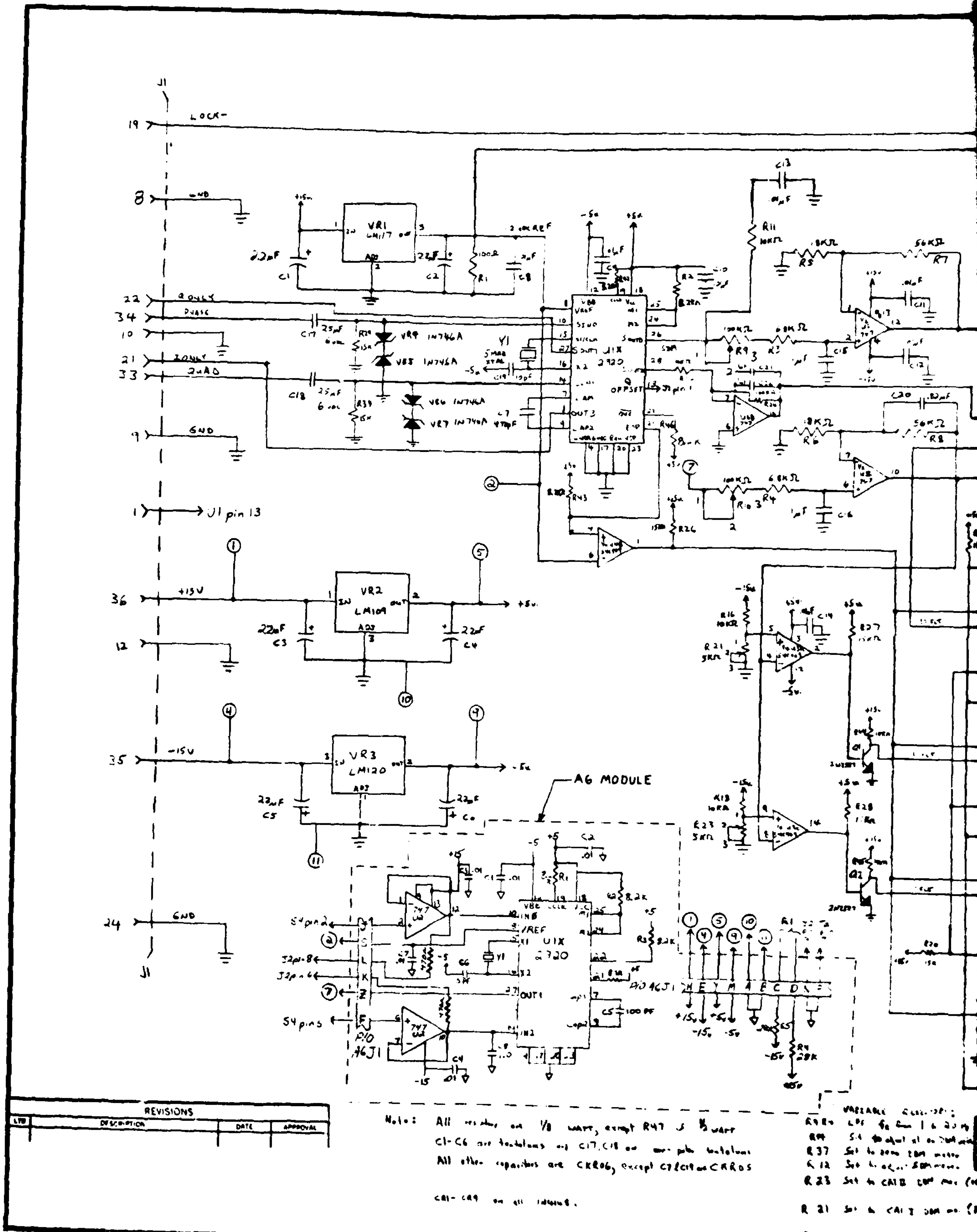
AEROSPACE AND ELECTRONIC SYSTEMS DIVISION BALTIMORE, MARYLAND

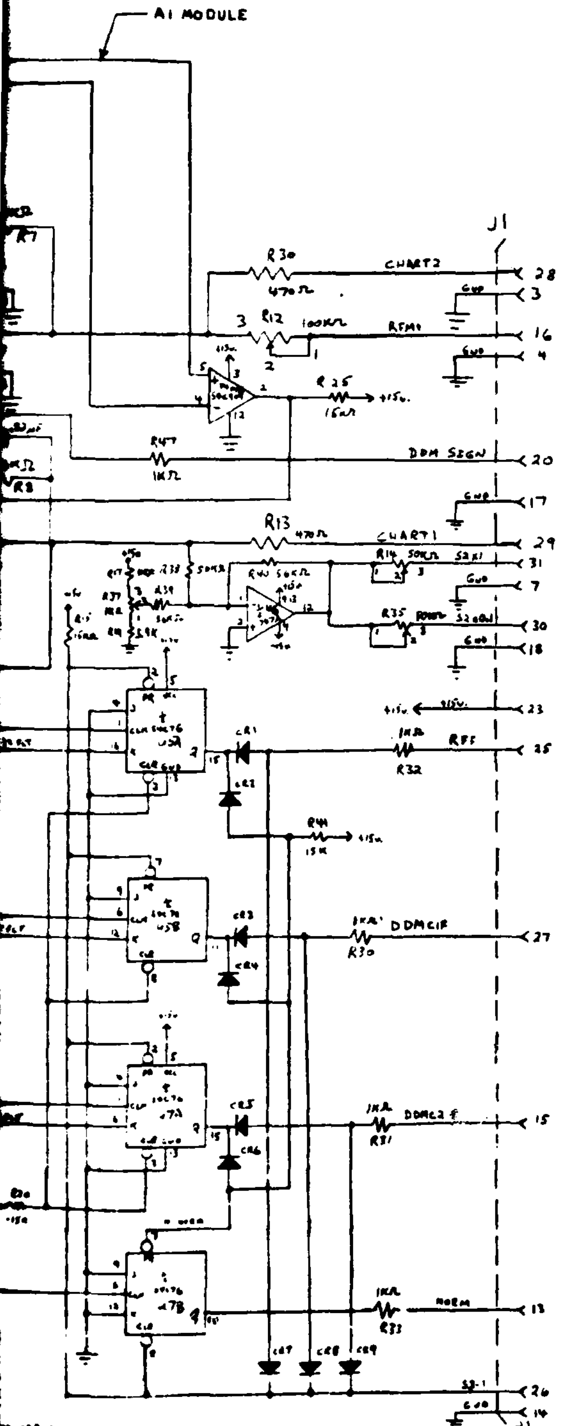
VOLTAGE CONTROLLED CRYSTAL OSCILLATOR
VCXO SCHEMATIC DIAGRAM
A5 MODULE

97942 | FIGURE 3-6

SHEET OF

2


J1
LOCK-
GND
VR1
LM117
VR2
LM109
VR3
LM120
+15V
-15V
+5v
-5v
U1X
2920
OFFSET
Y1
A6 MODULE
2920
747
REVISIONS
DESCRIPTION
DATE
APPROVAL
Note: All resistors are 1/8 watt, except R47 is 1/2 watt
C1-C6 are tantalums and C17, C18 are non-polar tantalums
All other capacitors are CKR06, except C7, C19 are CKR05
VARIABLE



SHEET REVISION STATUS					
5	4	3	2	1	SHEET NO
					LATEST REV LTR

NEXT ASSY | USED ON

APPLICATION

INTERPRET DWG IN ACCORDANCE WITH STDS PRESCRIBED BY MIL-D-1000

FORM CATEGORY

CONTRACT NUMBER DTFA01-80-C-10134

ORIGINAL DATE OF DWG 3/5/82

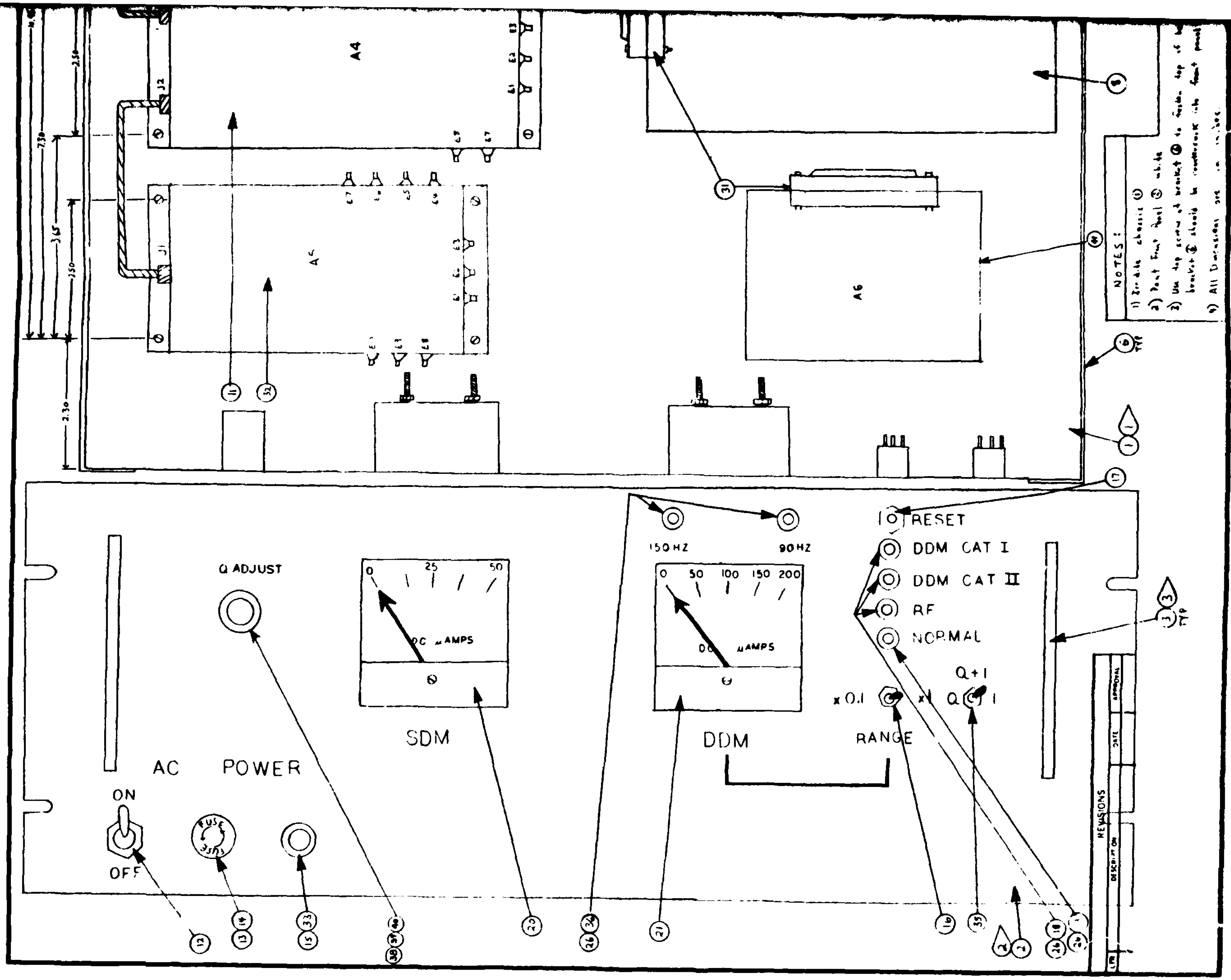
Westinghouse Electric Corporation

AEROSPACE AND ELECTRONIC SYSTEMS DIVISION BALTIMORE, MARYLAND

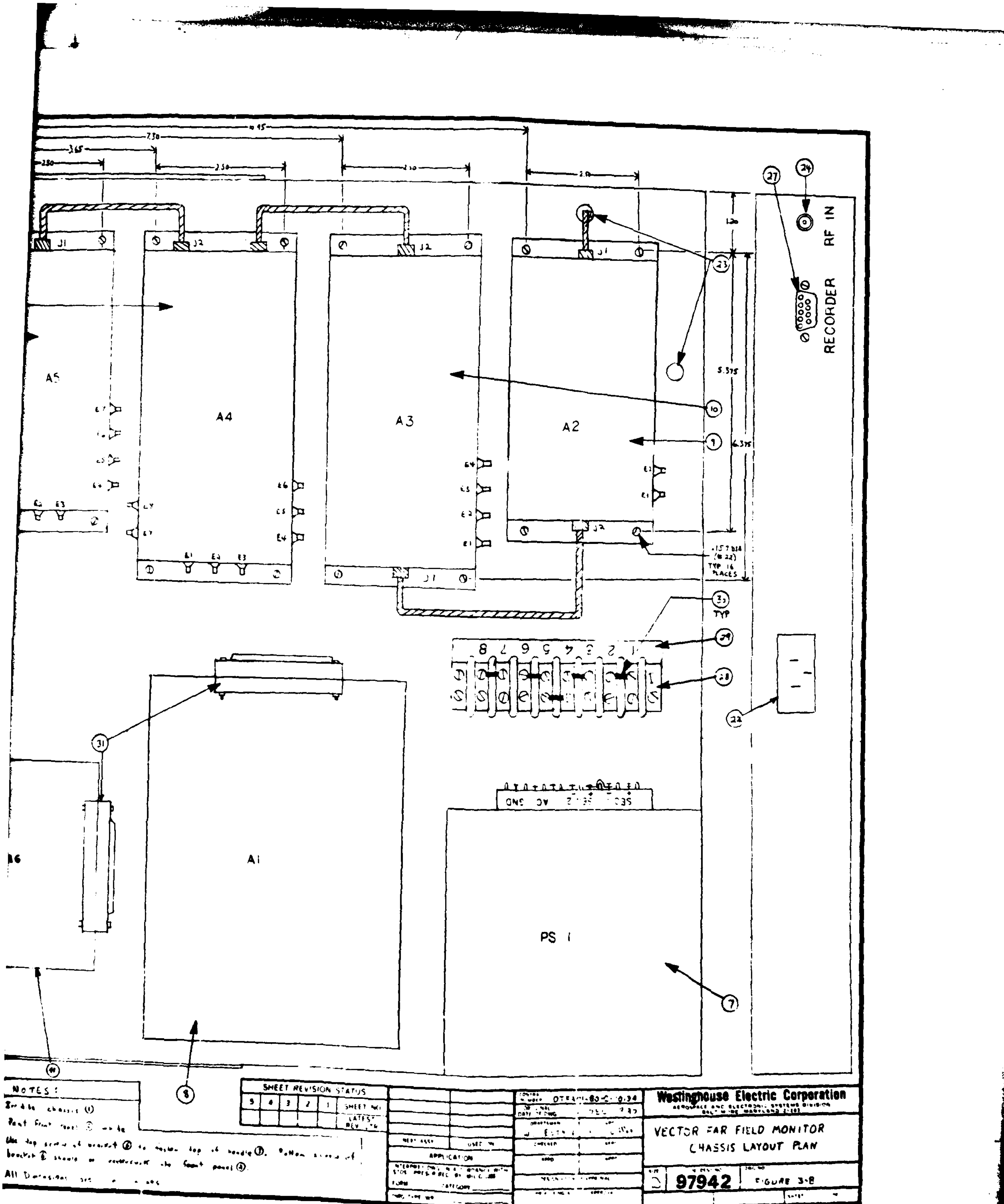
SIGNAL PROCESSOR A1 MODULE AND SPECIAL SIGNAL PROCESSOR A6 MODULE SCHEMATIC DIAGRAM

D | 97942 | FIGURE 3-7

2



A4
J2
J1
A5
A6
E1 E2 E3
E4 E5 E6 E7
E7 E8
2.30
2.50
3.65
7.30
Q ADJUST
SDM
0 25 50
DC µAMPS
DDM
0 50 100 150 200
µAMPS
150 HZ
90 HZ
RESET
DDM CAT I
DDM CAT II
RF
NORMAL
x 0.1
x 1
Q
Q+1
RANGE
AC POWER
ON
OFF
FUSE
TYP
REVISIONS
LTR
DESCRIPTION
DATE
APPROVAL
NOTES:
1) Irridite chassis (1)
2) Paint Front Panel (2) white
4) All Dimensions are in inches.


RF IN
RECORDER
A5
A4
A3
A2
A1
PS 1
J1
J2
TYP
NOTES:
SHEET REVISION STATUS
SHEET NO.
LATEST REV. LTR
APPLICATION
NEXT ASSY
USED ON
Westinghouse Electric Corporation
VECTOR FAR FIELD MONITOR
CHASSIS LAYOUT PLAN
97942
FIGURE 3-8

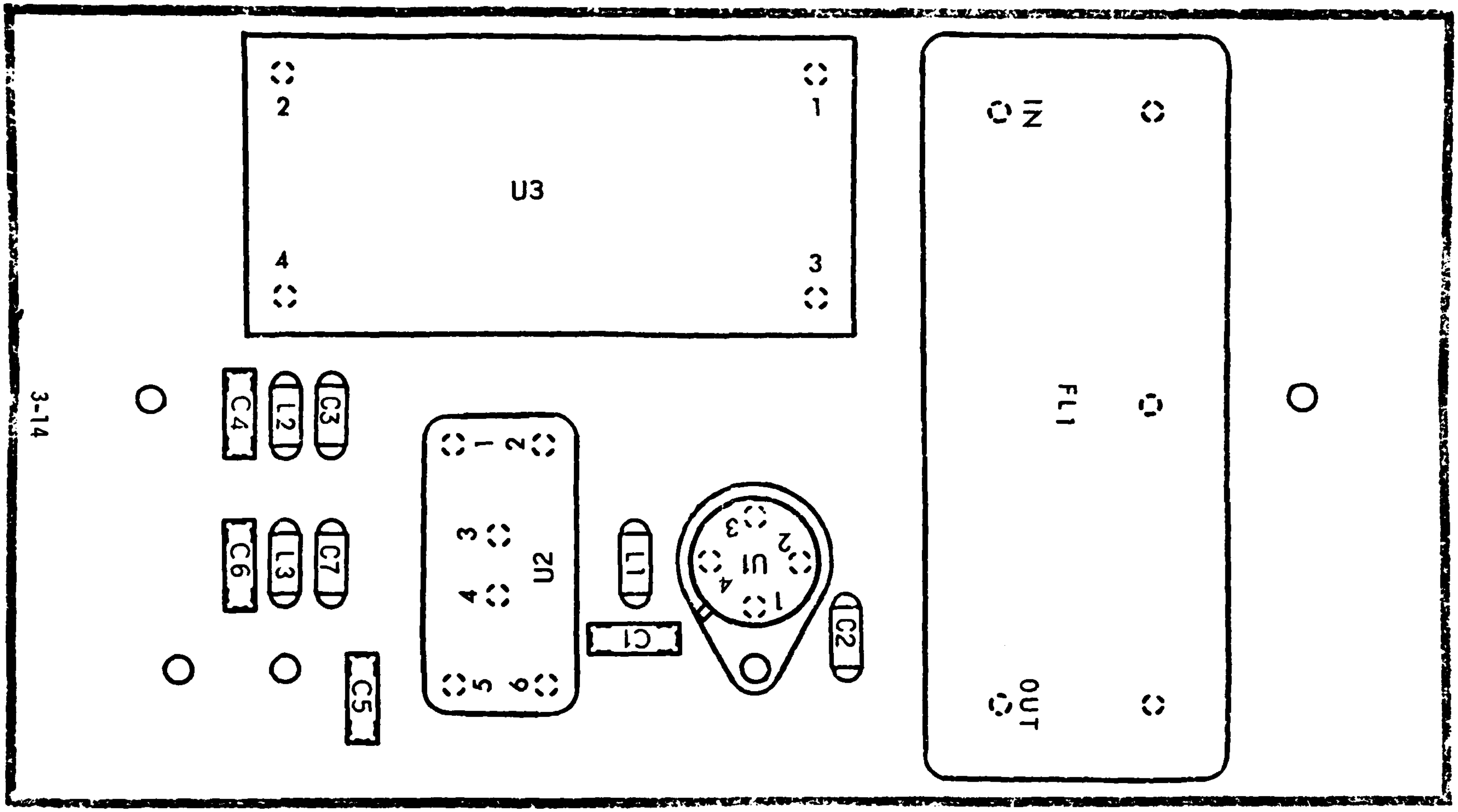


Figure 3-9. RF Amplifier/Local Oscillator PC Board Layout

3. The cascade of half-lattices introduces a situation where spurious responses in any half-lattice are rejected by the other units in the cascade.

4. All the crystals are identical.

Under the contract, two-pole filters with this technique were made. These filters displayed insertion loss less than 2 dB, 70 dB at ± 4 MHz, 100 dB rejection of the image, and smooth, ripple-free passbands. Using tuneable transformers and T05 crystal holders yielded a package volume of 1 cubic inch. These filters were built to be plug-in units by configuring the base terminals as a cluster with a weld screw in the middle; the terminals mate with sockets mounted in the mother board and are firmly seated by driving a nut onto the #4 weld screw. This is a convenient arrangement for changing the frequency of the VFFM receiver--one merely plugs in a new filter and new local oscillator to change from one frequency to another.

Alternate methods of designing this filter were investigated, but none were found to be satisfactory. Particularly attractive was the idea of making a single, tuneable filter to cover the band 108.1 to 111.95 MHz. Presently, there is no way known to make high Q ($>$ 1000), tuneable, reasonable size (1/10 cu. in.) resonators or filters by any technique. Alternatives intestigated included L-C ($Q \approx 70$), helical ($Q \approx 200$, large), BAW (untuneable) and SAW (high insertion loss and untuneable). It is, therefore, recommended that the preselector method which has already been proven, v.i.z, the new overtone quartz crystal cascade outlined above, be utilized until new breakthroughs in resonator technology become available. The frequency response curves for 109.7 MHz preselector filter is shown in Figures 3-10 and 3-11. The plug-in preselector is contained in the A2 module. Appendix B to this report contains the invention disclosure for this filter.

3.4.1.2 LOCAL OSCILLATOR MODULE

The A2 module also contains an MC308X1 multifrequency crystal controlled local oscillator. This plug-in unit provides a +8 dBm signal level to the balanced mixer for any desired frequency between 97.3 MHz to 101.3 MHz ($RF_{freq}-IF_{freq}$). The desired frequency of operation of the L.O. is selected by plug-in W-6 McCoy crystals and simple adjustments of two trimmer capacitors. The L.O. will provide frequency stability of ± 20 PPM over the temperature range of $-20^{o}C$ to $60^{o}C$ which is well within Environment II specifications.

3.4.2 10.7 MHZ IF/AGC AMPLIFIER (A3) MODULE

The schematic diagram for this unit is shown in Figure 3-4. The input signal is coupled from J1 to a 10.7 MHz IF filter. The input and output impedance of this filter is 50 ohms. This filter is described in detail in paragraph 3.4.2.1. The output of the 10.7 MHz filter is coupled to a Motorola MC1590, AGC controlled IF amplifier. This amplifier is followed by another identical amplifier which together with the first produces 80 dB gain at 10.7 MHz. The output of the first amplifier (U1) is applied to the input

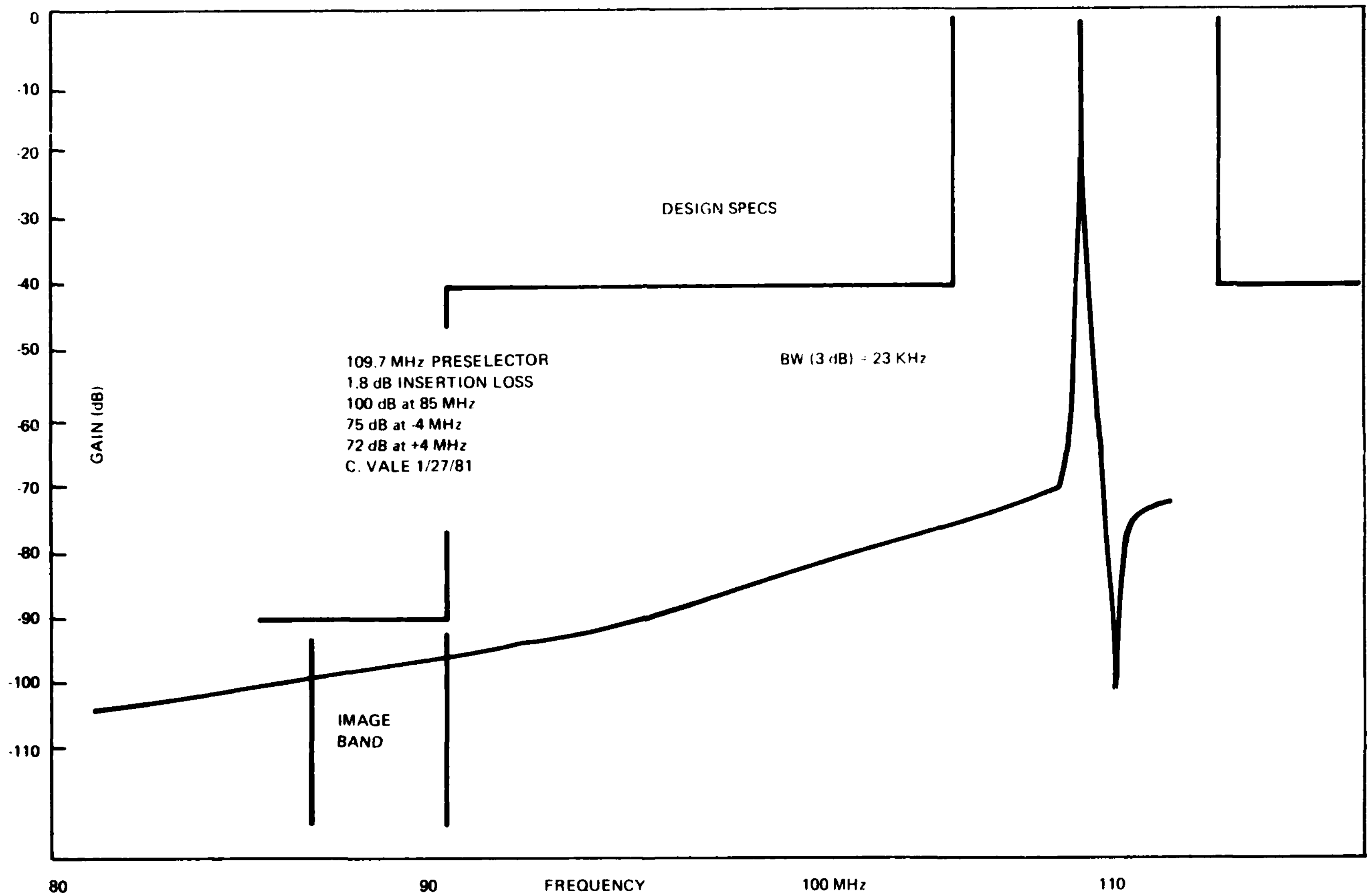


Figure 3-10. 109.7 MHz Preselector Response (Wide View)

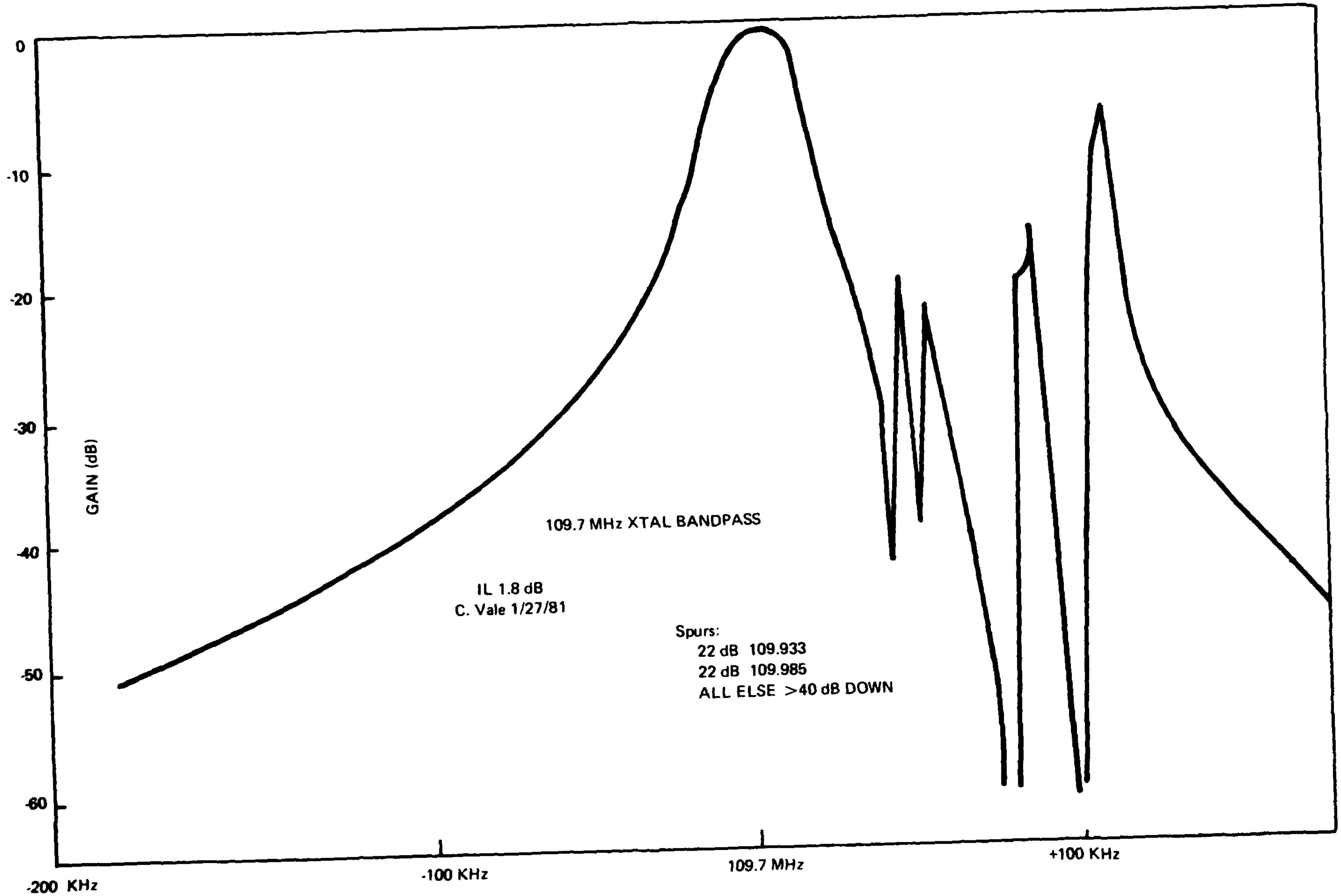


Figure 3-11. 109.7 MHz Preselector Frequency Response (Narrow View)

of the second amplifer (U2) through a parallel tuned matching network consisting of C9, C10, C11 and L3. The output of the U2 amplifier is matched to the 50 ohms input of the final IF amplifier (U3) with a tuned matching network C18, C19, C21 and L4. The IF output amplifier is a Watkins Johnson model A-79 as described in the RF/OSC section. This amplifier will provide the 0 dBm drive level required for the Synchronous Demodulation circuit board (A4).

Gain control of the IF amplifier stages is accomplished by applying a DC voltage to PIN 2 of amplifiers U1 and U2. Each amplifier stage will provide 70 dB of gain control as the AGC voltage is varied from +1.5V to +10 VDC. The AGC voltage applied to E4 varies from +0.6V to 0.85V as the RF input signal is varied from 1uV to 10mV. AGC amplifier U4, provides sufficient DC gain to the DC input signal at E4, to hold the IF output level between 0 dBm and +1 dBm over RF input range of -107 dBm to -27 dBm.

The 10.7 MHz IF amplifier circuitry is mounted on a 5.6 inches x 2.6 inches double-sided printed circuit board. The printed circuit board is mounted inside a 3-inch x 6-inch shielded module with SMA input/output connectors and feed-through terminals provided for DC voltage and AGC signal inputs. The 10.7 MHz IF amplifier operates from +15 VDC at 130 ma current drain. The PC board layout drawing for the A3 board is shown in Figure 3-12.

3.4.2.1 IF CRYSTAL FILTER

The VFFM measures the relative amplitude of a pair of close-set sidebands. It is obvious that the receiver's passband characteristic should be as flat as possible so that it does not yield measurement errors. This passband characteristic is determined by the combined response of the preselector and the IF filter. The preselector is very wide relative to the spacing of the sidebands; its bandwidth is about 20 KHz whereas the sideband spacing is about 100 Hz. The IF filter at 10.7 MHz is very narrow (4 KHz), therefore, any high amplitude ripple in the passband, whether part of the design or due to component errors, is unacceptable. Our design, therefore, was a Butterworth or maximally flat filter characteristic. Network synthesis transformation procedures can be used to apply this well-known characteristic to quartz crystal resonator filters; specifically, we used these techniques to transfer it to a quartz crystal ladder. This is a particularly desireable filter configuration because all the resonators (in this case four) are identical and interchangeable. Furthermore, there are no inductors or variable capacitors required in a crystal ladder filter; this contrasts with the commonly made half-lattice crystal filter where differential balanced transformers and several variable capacitors are used. A ladder is simply quartz crystals and fixed capacitors. The advantages are that the filter is compact, stable, and inexpensive. Over the expected temperature range experienced by this equipment measurements show that the distortion of sideband levels introduced by filter drift will be less than 0.02 dB. The filter has a smooth passband shape that monotonically approaches the stopband with no ripples due to component errors, design or spurious crystal responses. The power insertion loss is less than 1.5 dB and the stopband attenuation exceeds 70 dB exhibiting no spurious crystal responses. Figures 3-13, 3-14, and 3-15 present the frequency response curves for IF filters S/N 002, 003, and 004 respectively.

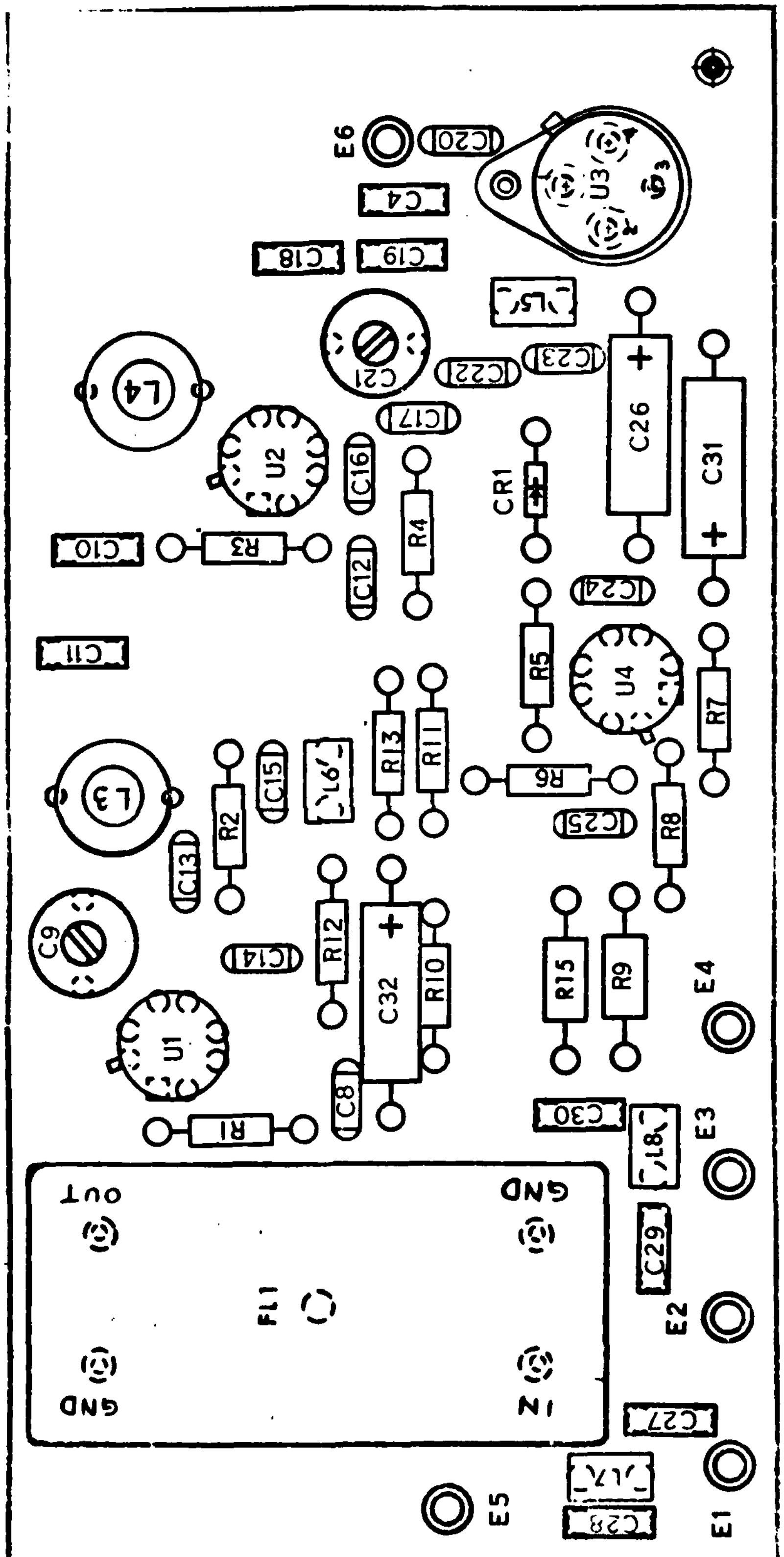


Figure 3-12 A3 Module PC Board Layout

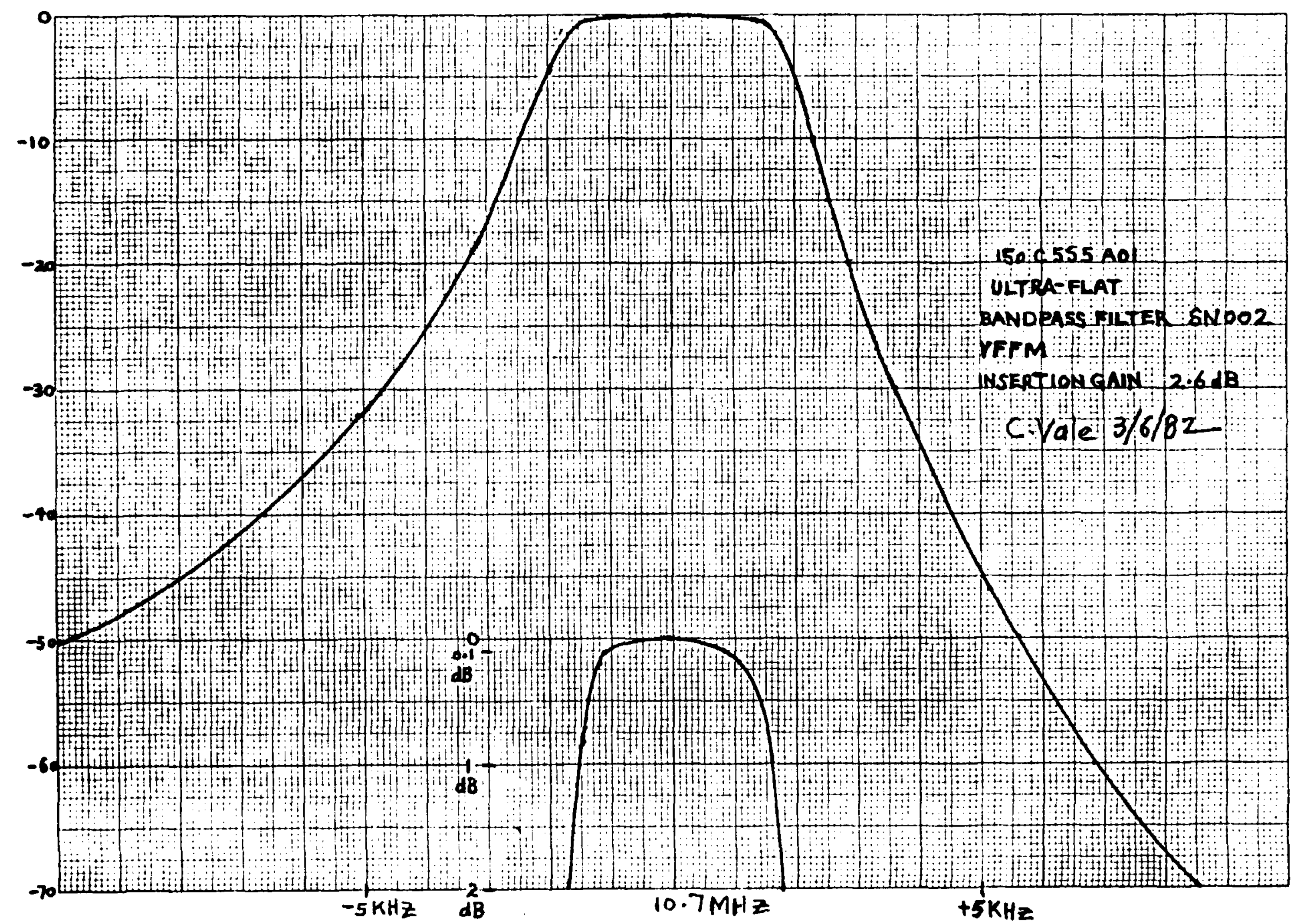


Figure 3-13. Frequency Response For IF Filter S/N 002

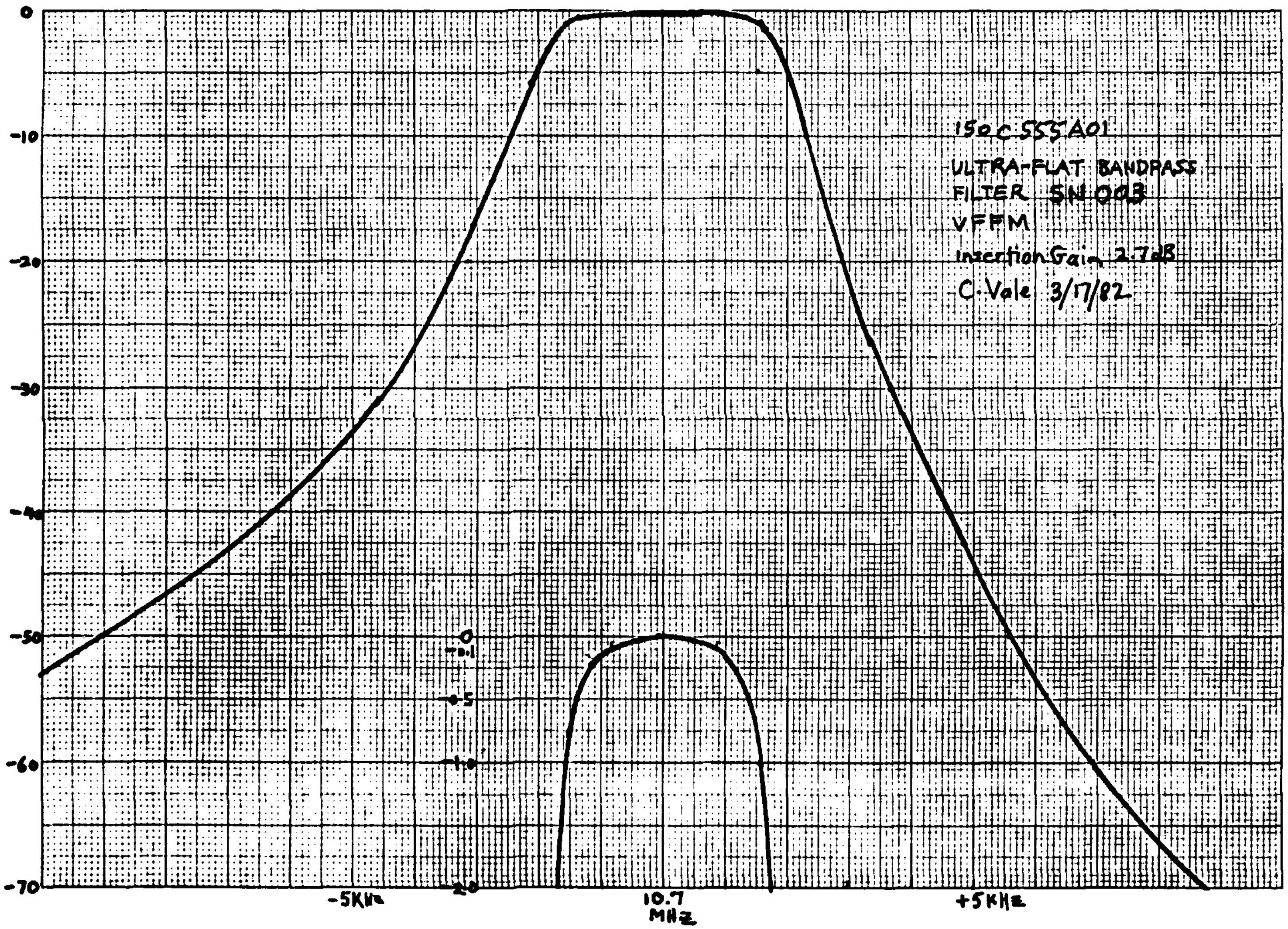


Figure 3-14. Frequency Response For IF Filter S/N 003

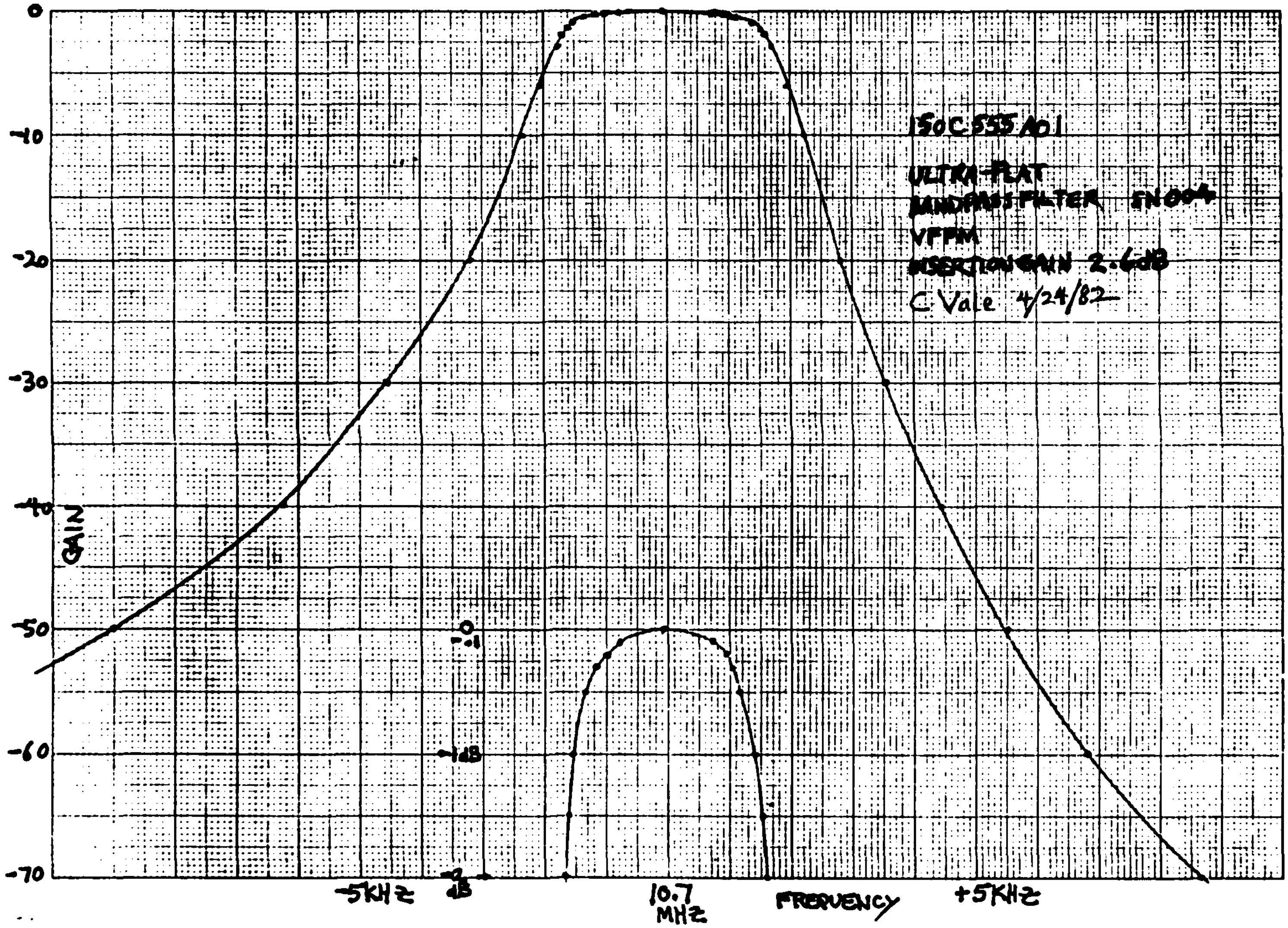


Figure 3-15. Frequency Response For IF Filter S/N 004

3.4.3 SYNCHRONOUS DEMODULATOR (A4) MODULE

The Synchronous Demodulator schematic is shown in Figure 3-5. The 10.7 MHz IF signal from IF amplifier A3 is applied to a two-way hybrid power splitter (U1) at 0 dBm power level. The output of U1, pin 1 is applied to the R-port input of a double balance mixer and the output of U1, pin 2 is applied to the R-port of another double balanced mixer U2. The output of a VCXO, mounted on module A5, is applied to A4-J3 input and is amplified by an RF driver unit U5. The output of U5 is applied to a phase shift network C23 and L2, which drives the L-ports of U2 and U3 in a quadrature relationship. The AM modulated RF signal applied to the R-ports of U2 and U3 mixes with 10.7 MHz signal injected at the mixer L-ports to produce the 90 Hz and 150 Hz modulation components at the output of both U2 and U3. Mixer U2 acts as a phase detector and a portion of U2 output is fed to the VCXO frequency control input through amplifier U7 allowing the phase locked loop (PLL) to lock the 10.7 MHz carrier input to the VCXO reference. Since the U2 and U3 mixer injection signals have a 90^{o} phase relationship, the outputs at E1 and E2 are locked in quadrature. The output tones at E3 are locked in phase to the VCXO and the output tones at E1, which represent the scatter signals are 90^{o} out of phase with the E3 output signals as well as the incoming carrier signal. Resistor pads R36 through R38 and R33 through R35 provide isolation between the in-phase (I) channel mixer and the quadrature (Q) channel mixer as well as assuring the required impedance at the mixer L-ports.

When the PLL is in the unlocked condition threshold comparator U4A, U4B and flip-flip U6 will generate a ramp which is applied to the VCXO control line through amplifier U7. This slow acting ramp function will cause the VCXO frequency to change until it moves within lock range of the incoming 10.7 MHz carrier. When the PLL is in the locked condition, the output level at pin 4 of the in-phase channel mixer (U3) will produce a positive DC voltage. This positive voltage appears at the input of comparator U8 and produces a logic "LOW" at analog switch U9 enable (Pin 9). When U9-9 input is low, the analog switch U9 will remove the ramp generator from the loop and cause the PLL to operate in a conventional manner. The threshold of comparator U8 is determined by a resistor divide network R29 and R30. The comparator threshold is set for +0.2 Vdc which, therefore, prevents the PPL from locking until the DC level at U8 pin 4 exceeds 0.20 Vdc. Since the DC level at U8 pin 4 is directly proportional to the magnitude of the 10.7 MHz carrier signal, the PLL will not lock until the 10.7 MHz carrier level exceeds approximately 0.2 Vdc. The comparator (U8) analog switch (U9) and the ramp generator (U4, U6), therefore, will function to prevent the PLL from locking to low level sideband signals.

It should be noted in discussing the circuitry that although the ramp generator, analog switch and threshold comparator function especially well in preventing false locking of the PLL, there is a tendency for the PLL to lose lock if the input signal is momentarily disturbed. Perturbations to the input signal is a typical condition resulting from low flying aircraft as was discovered during recent field tests. It is recommended that this circuitry be modified to maintain a longer hold time when the PLL goes from a locked to an unlocked condition. The A4 module PC board layout drawing is shown in Figure 3-16.

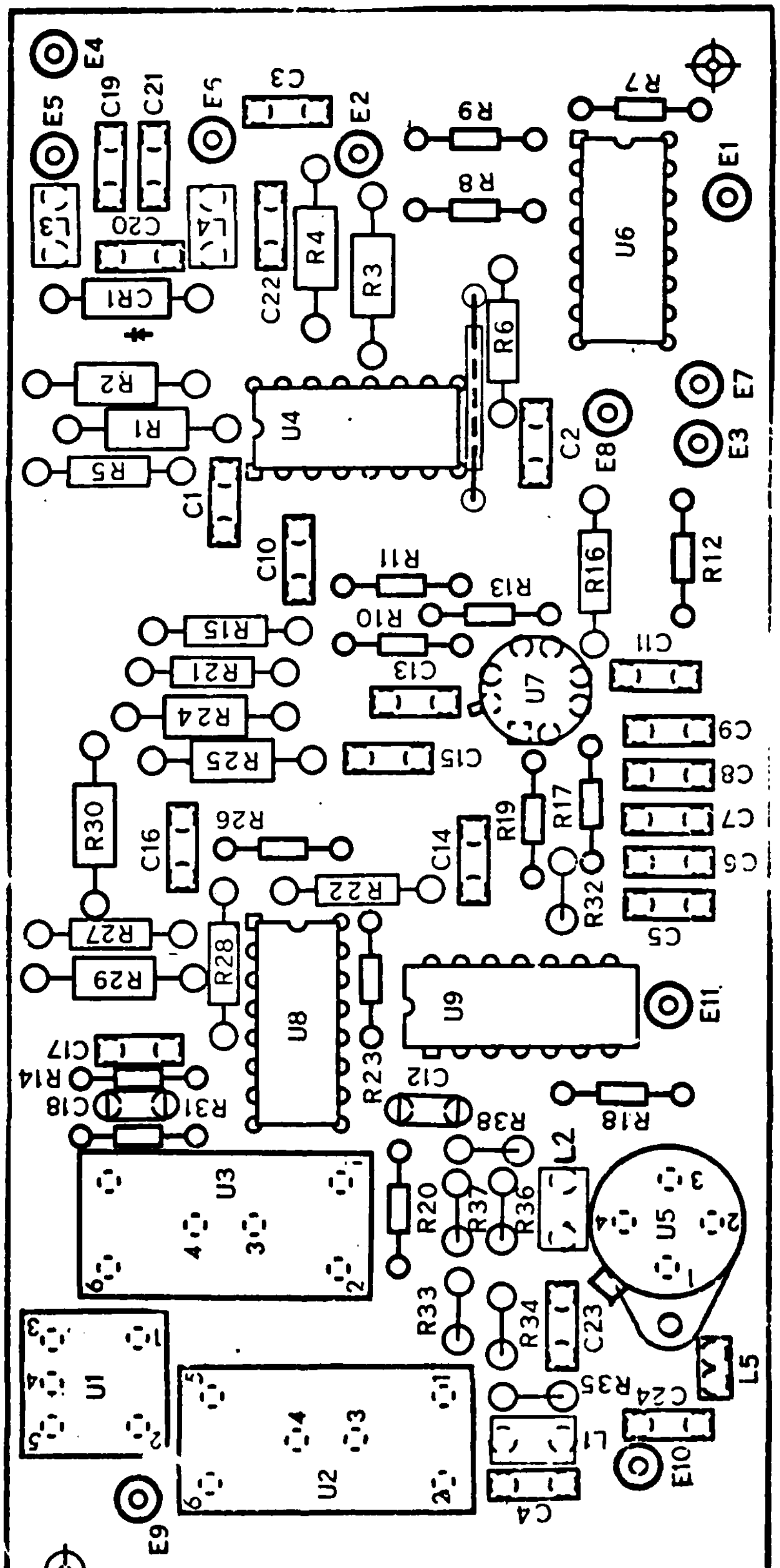


Figure 3-20. A4 Module PC Board Layout

3.4.4 VOLTAGE CONTROLLED CRYSTAL OSCILLATOR (VCXO) A5 MODULE

The VCXO on this circuit board forms part of the phase locked loop as described in paragraph 3.4.3. The schematic for this unit is shown in Figure 3-6. The DC frequency control input from the A4 module is applied to U1 pin 3 from terminal E7. As the PLL ramp generator sweeps the control voltage from -5Vdc to +5Vdc, the VCXO frequency will swing from 10.696 MHz to 10.704 MHz. The VXCO output frequency from U1 pin 2 is applied through coupling capacitor C7 to the output connector A5-J1. Capacitor C16 forms part of the PLL filter to sufficiently attenuate the AM sideband signal commponents.

The in-phase (I) channel and quadrature (Q) channel inputs are applied to this circuit board on terminals E4 and E5 from the Synchronous Demodulator (A4) circuit board. These inputs are applied to the inputs of two low pass, active filters, U2-A&B and U3-A&B. Since the analog signals on the I&Q channel outputs are coupled to a digital signal processor, the filters are required to prevent alliasing.

Amplifier U2-A, C4, C5, C7, R1 and R2 form a three-pole active low pass filter for the Q-channel signal. Amplifier U3-A, C10, C11, C12, R9 and R10 form another identical filter for the I-channel signal. These filters produce approximately 44 dB of attenuation to signals equal to or greater than 3 KHz. Amplifier U2-B, U3-B and associated resistors provide sufficient gain and drive level to interface the I&Q channels with the digital signal processor.

The A5 module PC board layout drawing is shown in Figure 3-17.

3.4.5 SIGNAL PROCESSOR (A1) MODULE

The Signal Processor Circuit (A1) Board uses in-phase and quadrature inputs which contain 90 Hz and 150 Hz components. These signals are processed to produce Sum of the Depths of Modulation (SDM), Difference in the Depths of Modulation (DDM), direction indicator of DDM, and fault indicator lamp drivers. The schematic diagram for the A1 board is shown in Figure 3-7.

The processing is done in firmware in Intel's 2920 Signal Processing IC. The inputs to the chip are dc-blocked (C17, C189) and clamped at 3.9 volts (VR4-VR7) to prevent overload at the 2920.

The SDM output is filtered by an adjustable low pass filter (R3, R9, C15) with a cut-off frequency from 2-20 Hz. It is then buffered (U2A) and sent to both a chart recorder output and also to a SDM meter output. A gain adjust (R12) is available for the meter.

The DDM output from the 2920 goes through another adjustable low pass filter (R4, R10, C16) of the same range. The signal is buffered by (U2B), but it also contains a meter damper (C20). At this point the DDM level goes to three places. The first is to a connector to provide a chart recorder output. The second is for fault detection. A comparitor (U3A) signals an error if CAT I DDM maximum limit is exceeded and can be adjusted by R21. Likewise U3B signals an error if CAT II DDM maximum limit is exceeded. These signals are level shifted (Q1, Q2) and latched into a flip-flop (U5B, U7A).

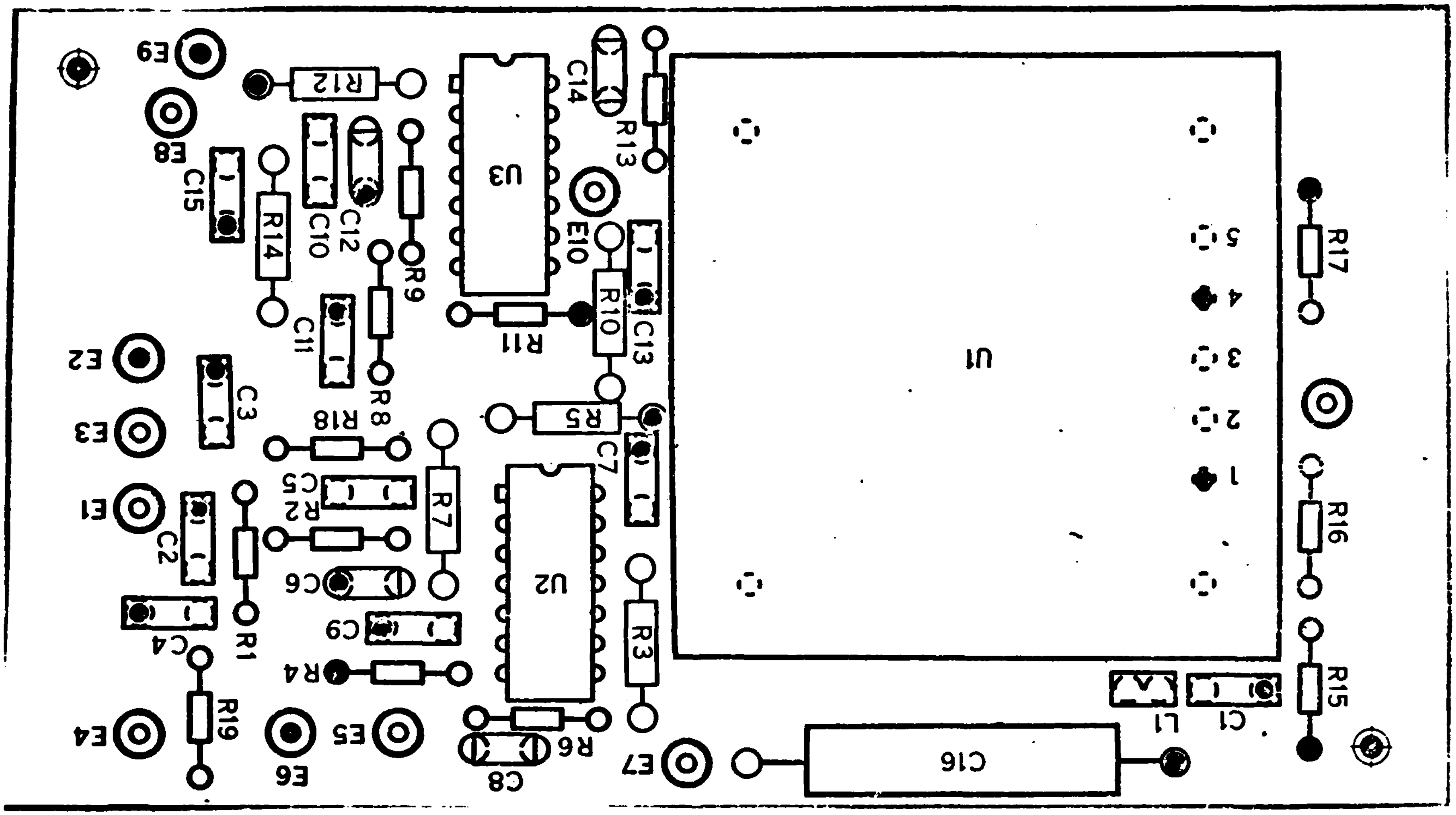


Figure 3-17. A5 Module PC Board Layout

The buffered DDM signal also controls a meter which reads DDM in two ranges (0-20 uA and 0-200 uA). There is a zero meter adjust (R37) and also gain adjusts for both the 0-20 uA). There is a zero meter adjust (R37) and also gain adjusts for both the 0-20 uA range (R35) and the 0-200 uA range (R14).

A "LOCK" signal from the IF signifies a lock condition in the phase lock loop circuitry. This signal is compared to a reference (U4A) and latched in a flip-flop (U5A). A fourth flip-flop (U7B) reads all other fault indicators and drives a "NORMAL" lamp. A reset button clears all flip-flops and also performs a lamp test (S3, CR7-CR9).

Three regulators (VR1, VR2, VR3) regulate the ±15 volt supply to ±5 volts and + 1.2 volts for use on the board.

The calculations performed in the 2920 are shown in the flow chart in Figure 3-18. The program used is presented in Appendix A under 2920 #1.

Both in-phase and quadrature inputs are filtered for both the 90 Hz and 150 Hz components. Each of the outputs from these filters go through envelope detectors which involve absolute value, peak detector, and averaging algorithms. The sum of the 90 Hz and 150 Hz in-phase components are output as SDM and the difference is used as the in-phase component of the DDM. The 90 Hz and 150 Hz quadrature components are added to produce the quadrature component of the DDM. These two components are then formulated in the square root of the sum of the squares to produce the magnitude of DDM which is then output after a level shift. The square root algorithm uses a piece-wise linear approximation.

The final value output from the 2920 is the sign of the DDM and is the sign of the in-phase difference amplified to full scale.

The 2920 uses a 5 MHz clock and operates at a 6.5 KHz sample rate/program loop execution rate.

The analog microprocessor was selected to perform the major functions required of the signal processor and the output circuitry. There were several advantages of this approach over the conventional analog approach: (1) the microprocessor is more versatile in that any parameter changes required during the development phase could easily be implemented by simple keyboard entries; (2) improved accuracy over the proposal approach was also realized since all calculations are performed numerically for sums, differences, and the square root of $(i^2 + q^2)$, etc.; (3) test time was minimized, since the filtering functions were accomplished with digital filters which required no hardware adjustments.

The INTEL 2920 analog microprocessor was selected to perform most of the functions required of the Signal Processor and output circuit board. The 2920 contains a sample and hold, A/D converter, MUX, digital microprocessor, UV erasable program ROM, RAM, D/A, and output MUX. It contains circuitry to handle four analog inputs and eight user specified audio or digital outputs.

SIGNAL PROCESSOR FLOW CHART

(Lables in parenthesis are program variable names)

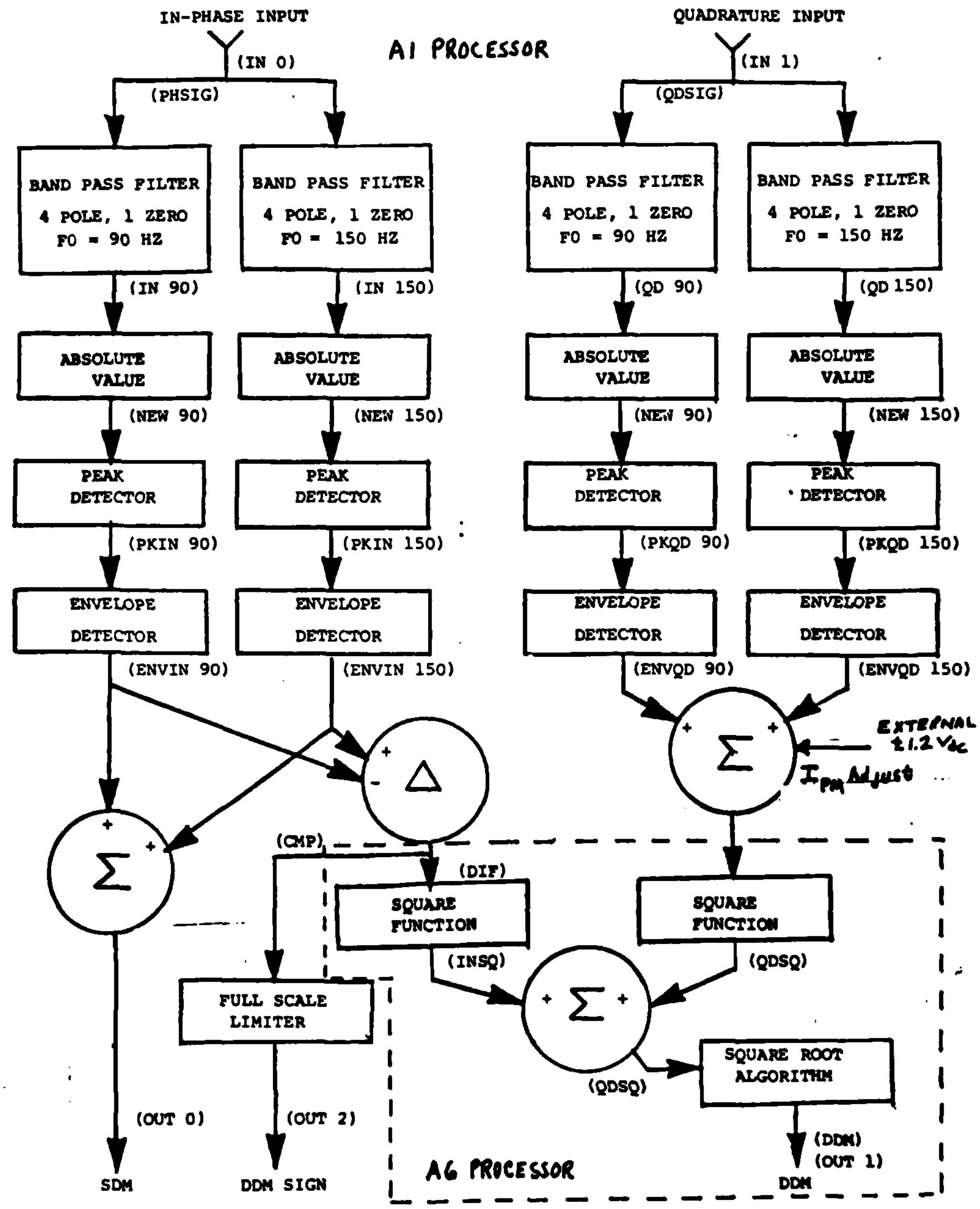


Figure 3-18. Signal Processor Flow Chart for VFFM

Since the contractor had the software support package (simulator, assembler, prom programmer) available in-house, the decision to go with digital process was simplified. It should be noted that improved system reliability has been achieved by keeping the number of analog circuits in the signal processor to a minimum. Processing is performed in real time with a 400 nanosecond sample update rate. The PC board layout drawing for the A1 module is contained in Figure 3-19.

3.4.5.1 DERIVATION OF SQUARE ROOT ALGORITHM FOR THE SIGNAL PROCESSOR

The algorithm which had been intended to be used in order to compute the magnitude of the scattered ($\sqrt{i^2 + q^2}$) signal independent of reflection phase, was found to have a maximum three percent error depending on phase. In order to improve upon this, a piecewise linear approximation was made for the $\sqrt{X}$ in the form MX+B where M and B are constants determined by the region of the phase curve they arrived at. This approximation had to be made compatible with the INTEL 2920 program since no branching or looping is possible, all calculations must be made in a straight through pass, several equations with low percent error were found, but the biggest problem was that the segments had to be broken into powers of two (conditional only on one bit at a time of x). Segments were then chosen as 1→1/2, 1/2→1/4, 1/4→1/8, 1/8→1/16, etc. Small values were predominant since under normal conditions (no scatterers) produce $i^2 + q^2 = 0$. This resulted in so many equations, that calculating each set of equations conditionally would take over 80 program steps, which was entirely too many. Plots were generated and curves shifted until only two equations were needed, and all further calculations were merely a shift by powers of two. This was an operation easily performed on the INTEL 2920. Table 3-1 lists the equations used for the square root algorithm. As can be seen all of these calculations are shifts by powers of 2. Also, once M1, M2 B1, and B2 are calculated, the final answer is easily obtained by shifting the previous calculation by powers of 2. This can be done in just one program step per segment of the curve. With the piecewise linearization broken down to the above a equations a maximum error over the entire range is 0.83 percent with an average error or 0.5 percent well below the three percent error produced by the former algorithm. All of these calculations can be done in 31 program steps. The computations are done in the order listed with each equation being computed only if that particular bit of x is set (0-8 respectively).

3.4.6 SPECIAL SIGNAL PROCESS FOR Q-CHANNEL ADJUSTMENT (A6) MODULE

This schematic diagram for the (A6) module is also shown on Figure 3-7. This board essentially represents the work that was performed under contract modification No. 3 to incorporate a design feature which would provide adjustment for localizer transmitter incidental phase modulation (I_{PM}). The A6 board interfaces with the A1 board in order to provide a DC offset input at the sum output of the Q-channel. This voltage adjustment is provided by a pot (R1) located on the front panel of the VFFM unit. This board contains a separate 28 pin INTEL 2920 microprocessor, a 5 MHz crystal (Y1) and a buffer amplifier (U2). Resistors (R4) and (R5) are

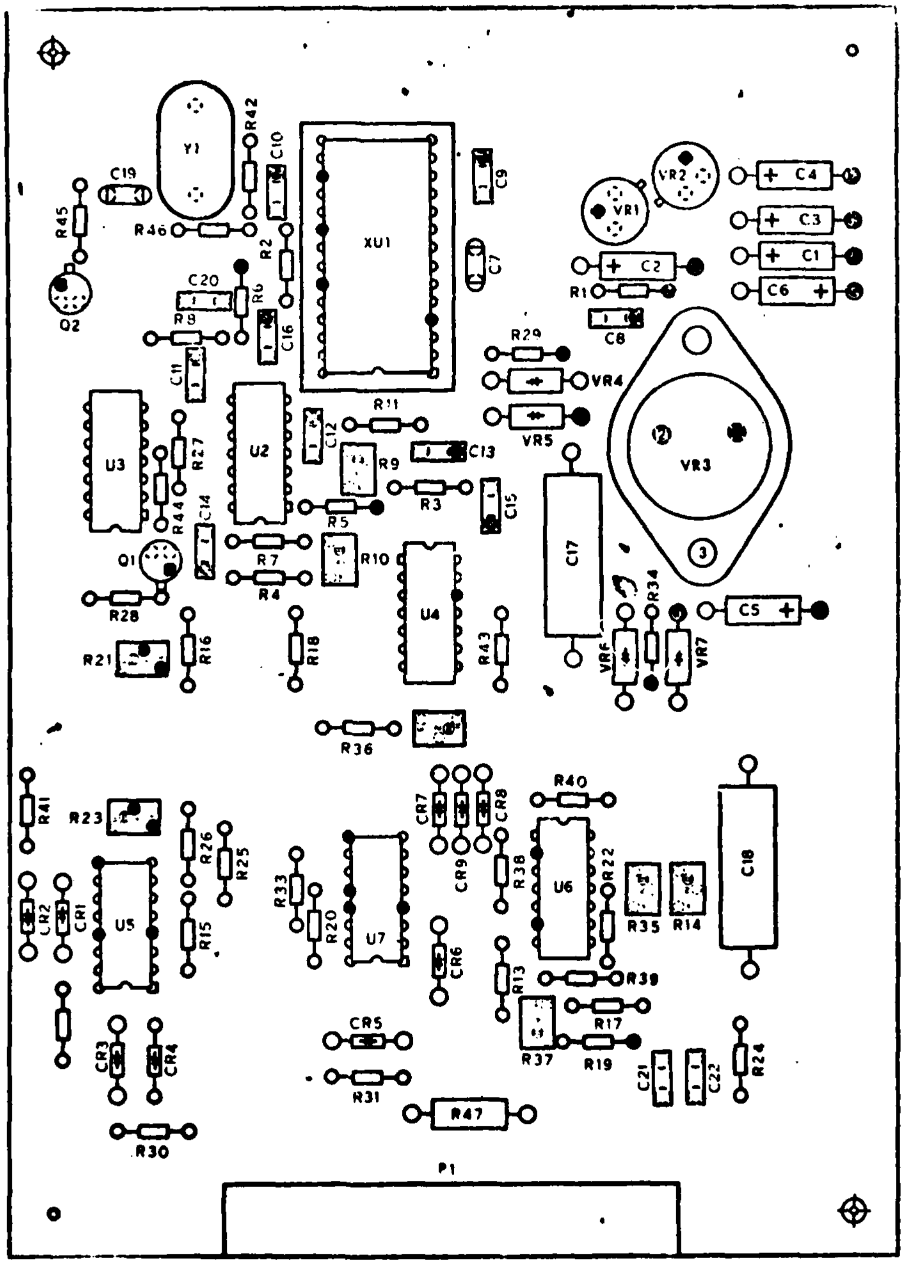


Figure 3-19. A1 Module PC Board Assembly

TABLE 3-1. EQUATIONS FOR SQUARE ROOT ALGORITHM

FOR X	M	B
$0 \leq X \leq 1/256$	0	0
$1/256 \leq X \leq 1/128$	M1	$B1 \times 2^{-3}$
$1/128 \leq X \leq 1/64$	M2	$B2 \times 2^{-3}$
$1/64 \leq X \leq 1/32$	$M1 \times 2^{-1}$	$B1 \times 2^{-2}$
$1/32 \leq X \leq 1/16$	$M2 \times 2^{-1}$	$B2 \times 2^{-2}$
$1/16 \leq X \leq 1/8$	$M1 \times 2^{-2}$	$B2 \times 2^{-1}$
$1/8 \leq X \leq 1/4$	$M2 \times 2^{-2}$	$B2 \times 2^{-1}$
$1/4 \leq X \leq 1/2$	$M1 \times 2^{-3}$	B1
$1/2 \leq X \leq 1$	$M2 \times 2^{-3}$	B2

where $\sqrt{x} = Mx+B$

and $M1=2^{2}+2^{1}+2^{-1}+2^{-3} = 6.625$

and $M2=2^{2}+2^{-1}+2^{-2} = 4.75$

and $B1=2^{-2}+2^{-4}+2^{-6} = 0.296875$

and $B2=2^{-2}+2^{-3}+2^{-5}+2^{-7} = 0.4140625$

connected to the front panel pot to make up a voltage divider network with an adjustment range of ±1.2 Vdc which is fed to U1X pin 13. All components are mounted on a 3x4 inch double sided printed circuit board which is mounted to the chassis with standoffs. The board can be removed from the chassis by disconnecting the 23 pin connector (P1) and removing the four #4-40 mounting screws. The assembly language program used to program U2X is given in Appendix A under 2920 No. 2. The flow chart for the special signal processor is also contained on Figure 3-18. The A6 PC board assembly diagram is shown in Figure 3-20. The assembly program is given in Appendix A under 2920 #2.

3.4.7 CHASSIS/CABINET ASSEMBLY

3.4.7.1 CHASSIS

The chassis assembly drawing is shown in Figure 3-8 and the chassis wiring diagram is provided in Figure 3-2. The chassis is a 17 X 17 X 3 inch irridited aluminum assembly which is predrilled to mount the four RF modules, two signal processor modules and one power supply. A type N bulkhead feed through connector (J1) serves as the RF input and is mounted on the rear of the chassis. The rear chassis panel also contains a 9 pin minature connector (J2) for the chart recorder output, and an AC input connector (P2).

3.4.7.2 FRONT PANEL

A 19 X 7 X 1/8 inch panel is attached to the chassis. The front panel contains the AC power switch (S1), .5 amp SLO BLO fuse (F1), DDM meter (M1), SDM meter (M2) power on lamp (DS1), DDM range toggle switch (S2), mode toggle switch (S4), alarm reset pushbutton switch (S3), Q-offset adjust pot (R1), and six LED panel lamps (CR-1 through CR-6).

3.4.7.3 EQUIPMENT CABINET

The chassis is slide mounted inside a 20 x 18 x 10 inch equipment cabinet. Mounting hardware is provided to lock the chassis in place. Carrying handles are provided on the sides of the cabinet.

3.5 EQUIPMENT OPERATING INSTRUCTIONS

3.5.1 GENERAL

Turn on, operating, and turn off instructions for the VFFM, which may be used for unattended operation are given. Once the equipment is turned on and the lamp and meter indications are checked, no additional operating checks or adjustments are required. Dual DDM alarm limit adjustments are provided. These alarm limits have been factory set to cause the DDM alarm light to come on at approximately 15 microamps for CAT I and 10 microamps for CAT II. In order to change the alarm setting, it is necessary to set the voltage reference levels for comparitors U3A (CAT I) and U3C (CAT II) on the A1 board. Variable resistors R21 and R23 provide this adjustment. The "zero" DDM adjust has also been factory adjusted using the Precision Monitor Calibrator as the reference. If it should become necessary to "zero" adjust

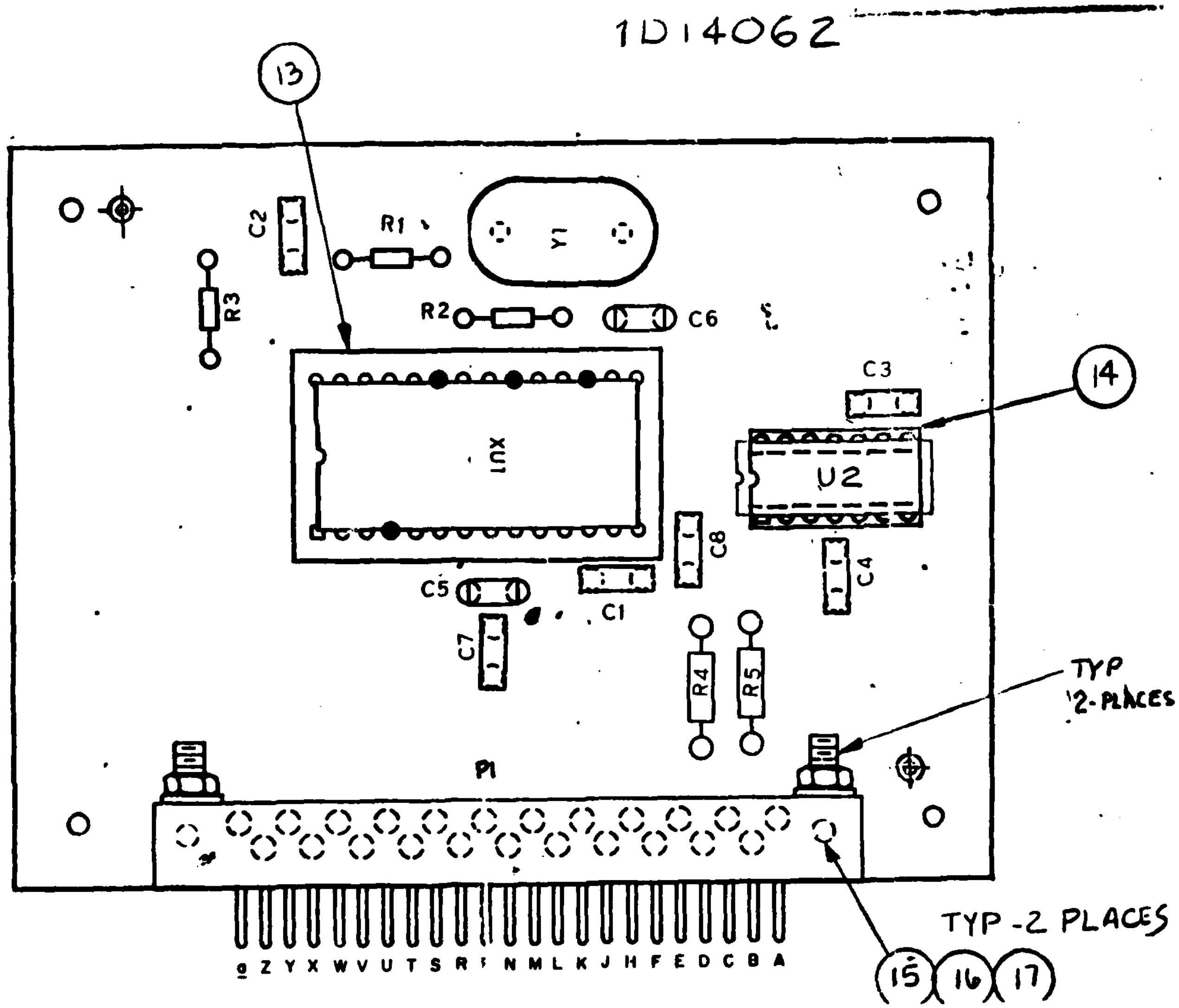


Figure 3-20 A6 Module PC Layout

the DDM reference level, variable resistor R37 is provided. The gain adjustment for the DDM meter X1 and X.1 ranges are provided by variable resistors R14 and R35. The SDM meter has been calibrated to indicate the total modulation level. Variable resistor R12 (A1) is provided if any adjustment becomes necessary.

3.5.2 SITING

The VFFM is designed to operate on the extended ILS runway centerline in the vicinity of the middle marker beacon station. This location is typically 3000 to 4000 feet from the runway threshold. The elevation of the monitor antenna should be of sufficient height to provide a minimum of 20 microvolt input signal level to the monitor, without violating the obstruction clearance criteria. The maximum distance from the receiving antenna to the monitor input should not exceed 200 feet. The VFFM requires some convection cooling during normal operation. The rear of the equipment cabinet should not be obstructed.

3.5.3 TURN-ON PROCEDURE

(a) Plug power cord into 120 VAC 1 Phase 60 Hz source.
(b) Set AC power switch to on position.
(c) Slide chassis out of cabinet to expose A1 board.
(d) Measure dc voltage present on pin 13 U1X of A1 board. Adjust "Q-Adjust" pot on front panel for 0.0 $\pm$ .002 Vdc at pin 13.
(e) Return chassis to closed position.

3.6 OPERATING PROCEDURES

(a) Connect antenna feed cable to RF input port at rear of chassis. Requires type N connection.

(b) Radiate CSB only signal from localizer, dummy up sideband.

(c) Verify that receiver is locked onto signal by observing SDM meter. With no RF signal the meter should read zero. When the receiver is locked, the meter reading should be 40 $\pm$ 4 percent.

(d) Set DDM range switch to X1 position.

(e) Set DDM mode selector switch to "Q" position.

(f) Observe reading on DDM meter. It should read the amount of localizer quadrature signal which must be compensated for.

(g) Adjust Q-Adjust pot to zero the DDM meter. Tighten locking knob on this pot after adjustment is made.

(h) Radiate normal localizer signal CSB + SBO.

(i) Set selector switch to "I" position. The reading should be essentially the same as measured on PIR.

(j) Set selector switch to "I&Q" position. The equipment is now in the vector far field monitor mode.

(k) Press the "RESET" button on the front panel. With button depressed, all four lamps should glow. With button released, only green normal lamp should glow, unless the indicated DDM exceeds an alarm level setting.

3.7 CHART RECORDING

A nine-pin miniature female connector is mounted on the rear of the chassis. A mating male connector/cable assembly is also supplied with each of the three VFFM units. Monitor outputs are available for the following parameters: (The second pin number is the return wire)

PIN NO. (J2)		PARAMETER
Signal	Return	
5	4	DDM (I&Q data)
3	1	SDM
6	7	Δ (I-channel only data)
8	9	Σ (Q-channel only data)

The signals at the recorder outputs are single ended with voltage swing less than ± 5 Vdc.

3.8 INSTRUCTIONS FOR TUNING THE LOCAL OSCILLATOR

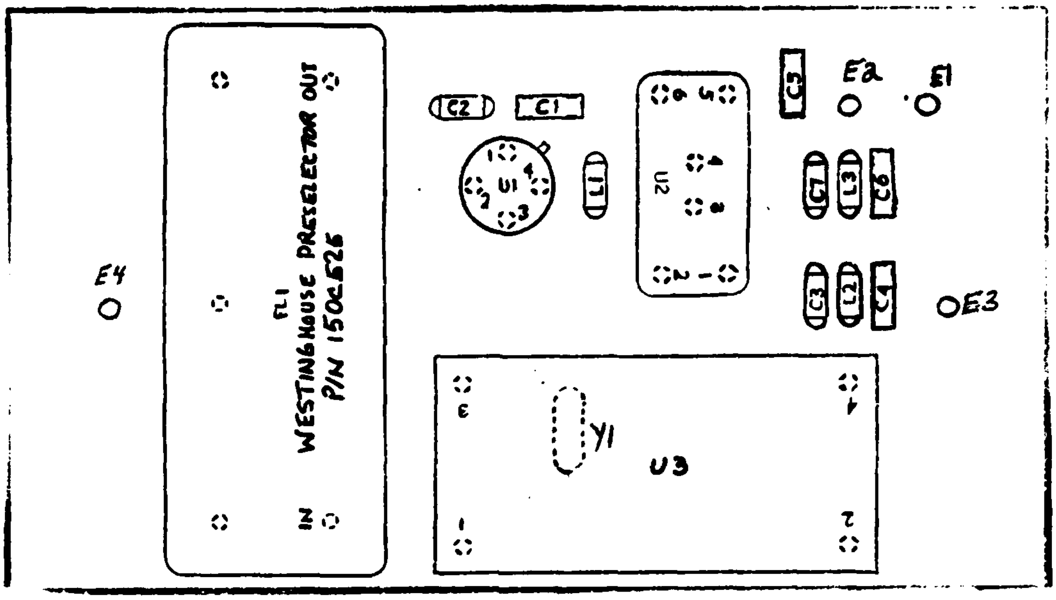
Although the VFFM receiver frequency cannot be changed without inserting a preselector filter corresponding to the desired localizer frequency, the following procedures are given for checking the output of the RF amplifier/local oscillator module (A2). Refer to Figure 3-21 for test setup.

(a) Remove front panel screws and slide chassis out of cabinet far enough to expose A2 module. AC power switch off.

(b) Disconnect semirigid coax cable between A2/J2 and A3/J1.

(c) Remove lid of the A2 RF shielded module by removing 10 screws.

(d) Connect signal generator output to RF input port on rear chassis panel. Set signal generator to desired localizer frequency and input level as shown on Figure 3-21.



A2 RF AMP/LO COMPONENT LAYOUT

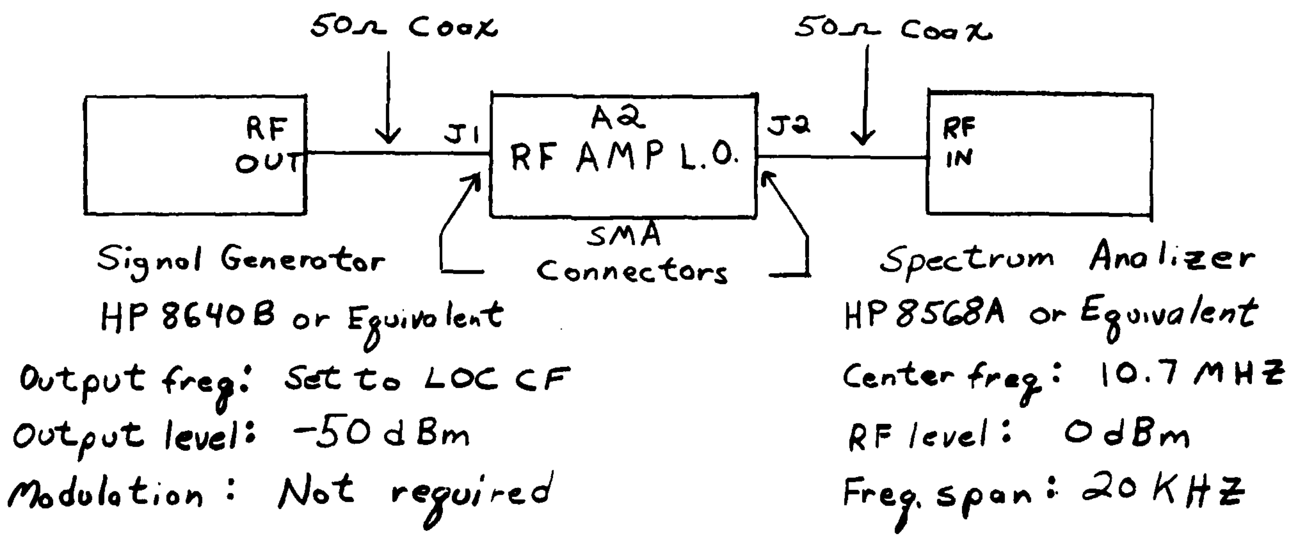


Figure 3-21. Test Setup for Tuning RF AMP/LO in A2 Module

(e) Connect A2/J2 to spectrum analyzer RF input port.

(f) Turn on VFFM AC power switch. Ensure that ball clips are connected to E1 and E2 of A2.

(g) Measure IF output frequency and level on spectrum analyzer. Frequency should be 10.7 MHz $\pm$ 20 Hz. Level should be -47 dBm (min) with -50 dBm in (minimum of 3 dB gain). If adjustment is required remove lid of U3 to expose trimmer capacitors.

(h) To coarse adjust RF level (required if signal is down in the noise) adjust "out" trimmer for maximum indication.

(i) To fine adjust RF level adjust "OSC" trimmer for maximum indication.

(j) To adjust output frequency adjust "FREQ TRIM".

(k) Replace lid on U3 and note change in level or frequency. Readjust if necessary to compensate for shielding.

Note: When cover is removed from U3 check L.O. crystal Y1 for correct frequency marking (Loc. Freq. -10.7 MHz) and proper pin alignment.

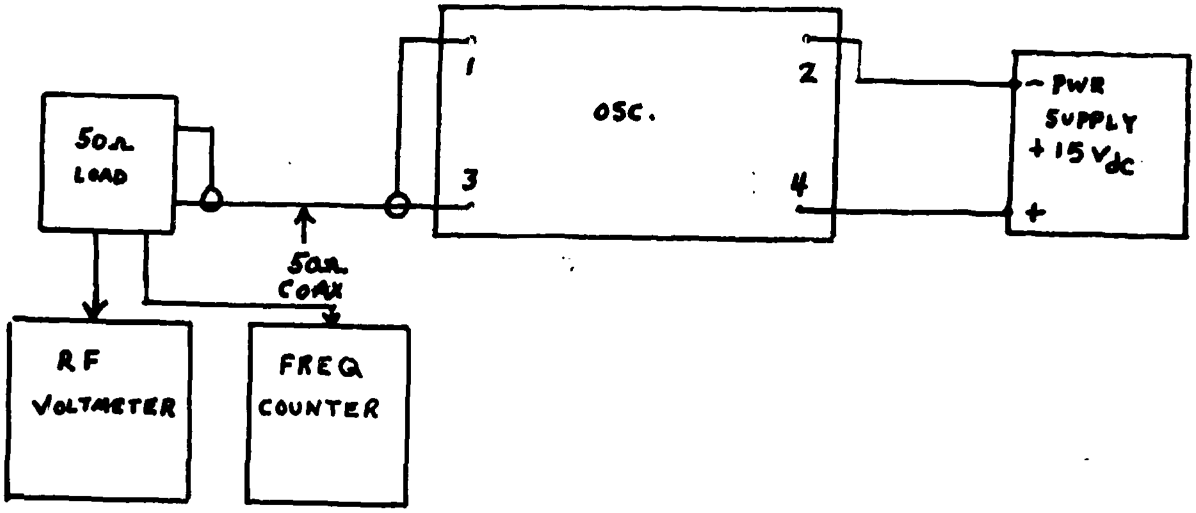
(l) Remove power and restore equipment connections to normal.

If a spectrum analyzer or signal generator are not available for tuning, the L.O, the L.O. unit can be tuned satisfactorily using an RF voltmeter and a frequency counter as described in Figure 3-22.

The layout of the equipment on the chassis is shown in Figure 3-23.

TUNING PROCEDURE, MC308X1

I. Test Set Up:



II. Tuning Procedure:

1. Set up equipment as indicated in Part I.
2. Adjust "Osc." trimmer for maximum indication on R.F. meter.
3. Adjust "OUT" trimmer for maximum indication on R.F. meter.
4. Repeat steps 2 and 3 for maximum indication on R.F. meter.
5. Adjust "TRIM" for frequency adjustment.

Figure 3-22. Alternate Test Setup for Tuning RF AMP/LO

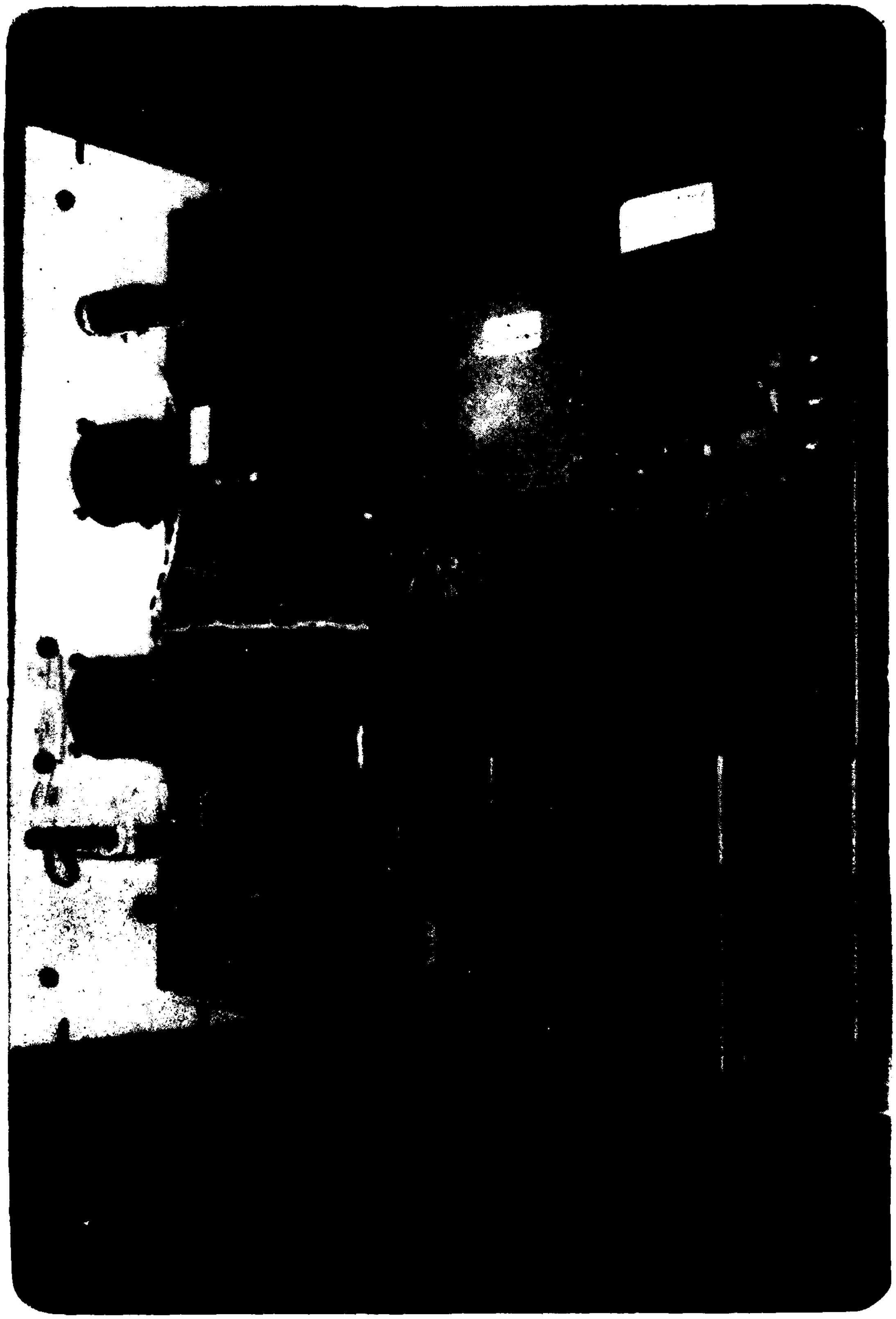


Figure 3-23. VFFM Chassis Layout

4.0 VFFM BENCH TESTS

4.0 VFFM BENCH TESTS

The VFFM equipment was subjected to extensive bench testing in the engineering laboratory during the design phase and prior to beginning field tests. The primary purpose of this testing was to determine the operating parameters of the receiver and processor circuits such as signal sensitivity, bandwidth, AGC action, selectivity, etc. This testing was carried out with the use of standard contractor supplied test equipment and special FAA furnished test equipment.

As an example of the important role which thorough bench testing played during the VFFM development, it was determined that highly accurate DDM calculations in the signal processor were extremely dependent upon good signal transfer characteristics (within 0.2%) between the rf input and the detected audio output.

4.1 USE OF THE ILS MONITOR PRECISION CALIBRATOR TYPE FA8920X S/N 1

This equipment was supplied under this contract as GFE and was used extensively during receiver alignment and calibration of the in-phase channel. This unit is a high quality signal generator that produces an rf carrier having adjustable and known modulation characteristics. It is used to verify correct response and proper alarm limit settings for ILS monitors and receivers. This equipment was used as the standard to which the Vector Far Field Monitor units were tested and aligned.

The calibrator was used only in the localizer mode which has an rf output range from +10 dBm to -90 dBm. The percent modulation level was adjustable from .002% to greater than .300% per tone and the DDM output level was adjustable from 0 to at least a .250 DDM for either 90 or 150 HZ tone predominance. The calibrator was limited in that it did not have a separate SBO output, as was required for fully testing a phase sensitive receiver. This deficiency was overcome by designing the ILS signal simulator described in paragraph 4.4.

4.1.1 INCIDENTAL PHASE MODULATION OF PRECISION MONITOR CALIBRATOR

The CSB output of this test equipment displayed high residual phase noise (incidental phase modulation) which resulted in a large qauadrature component as measured on the VFFM Q-channel. This resulted in a DDM output as great as 80 microamps and decreased during equipment warm-up to a minimum of 40 microamps. The phase noise present in the Monitor Precision Calibrator was the initial indication of a potentially similar response from a localizer transmitter. This suspicion was later confirmed and is discussed in paragraph 5-4. Bench test data was taken for each of the VFFM units relating DDM input from the calibrator versus DDM output as displayed on the VFFM DDM meter. Tables 4-1, 4-2, and 4-3 contain this data for VFFM S/N 001, S/N 002, and S/N 003, respectively.

TABLE 4-1.
DDM OUTPUT FOR VFFM S/N 001 VS. MONITOR PRECISION CALIBRATOR INPUT

MONITOR PRECISION CALIBRATION INPUT DDM		VFFM S/N 001 OUTPUT DDM (µA)	
Predominant 90 HZ	Predominant 150 HZ	90 HZ	150 HZ
0	0	2	2
.003	.003	4	3
.005	.005	5.5	5
.010	.010	11	10.5
.015	.015	15.5	15.5
.020	.020	20	20
.025	.025	25	25
.030	.030	29.5	30.5
.035	.035	34	36
.040	.040	39.5	42
.045	.045	44.5	49
.050	.050	49	56
.060	.060	60	65
.070	.070	69	80
.080	.080	80	92
.090	.090	92	105
.100	.100	101	119

Frequency: 109.7 MHZ
Input Level: -50 dBm

TABLE 4-2.
DDM OUTPUT FOR VFFM S/N 002 VS. MONITOR PRECISION CALIBRATOR INPUT

MONITOR PRECISION CALIBRATION INPUT DDM		VFFM S/N 002 OUTPUT DDM (μA)	
Predominant 90 HZ	Predominant 150 HZ	90 HZ	150 HZ
0	0	0	0
.003	.003	0	3
.005	.005	0	5
.008	.008	4	9
.010	.010	6	10
.013	.013	9	13
.015	.015	11	15
.018	.018	14	19
.020	.020	16	21
.023	.023	17	24
.025	.025	20	27
.028	.028	22	30
.030	.030	24	32
.040	.040	32	44
.050	.050	44	58
.060	.060	55	69
.070	.070	63	84
.080	.080	74	95
.090	.090	86	110
.100	.100	96	121

Frequency: 109.7 MHZ

Input Level: -50 dBm

TABLE 4-3.
DDM OUTPUT FOR VFFM S/N 003 VS. MONITOR PRECISION CALIBRATOR INPUT

MONITOR PRECISION CALIBRATION INPUT DDM		VFFM S/N 003 OUTPUT DDM (μA)	
Predominant 90 HZ	Predominant 150 HZ	90 HZ	150 HZ
0	0	0	0
.003	.003	4	1
.005	.005	7	4
.008	.008	10	6
.010	.010	12	8
.013	.013	15	11
.015	.015	16	13
.018	.018	19	16
.020	.020	20	18
.023	.023	22	20
.025	.025	25	22
.028	.028	26	25
.030	.030	28	27
.040	.040	36	38
.060	.060	55	58
.080	.080	72	80
.100	.100	90	105

Frequency: 109.7 MHZ
Input Level: -50 dBm

4.2 USE OF THE PORTABLE ILS RECEIVER (PIR) TYPE FA-9392 S/N 1096

This equipment was supplied under the contract as GFE and was used during both the bench testing and field testing work. The PIR is a completely solid-state, battery operated, portable VHF/UHF receiver used to measure the signal characteristics of an ILS. It is the standard test equipment used by FAA maintenance personnel to set and recheck DDM levels, both at the localizer station and at remote tests points in the localizer radiation field. It is to be noted that a tracking error existed between the digital DDM display on the Monitor Precision Calibrator and the analog DDM meter on the PIR. Table 4-4 illustrates the deviation between these two GFE test equipments. The gain values in the software for the microprocessors and the gain pots for the meter driving circuits in the VFFM units were set to approximate the DDM output levels of the Monitor Precision Calibrator. In order to utilize the PIR at the proposed test sites the PIR was outfitted with the following crystals:

TEST SITE	LOCALIZER FREQ.	PIR L.O. FREQ.
BWI R/W 10	109.7 MHZ	67.4 MHZ
BWI R/W 15R	111.7 MHZ	68.4 MHZ
FAATC R/W 13	109.1 MHZ	67.1 MHZ

4.3 CHART RECORDING THE DDM OUTPUT OF THE PIR

The PIR was a valuable tool during the performance of both bench and field testing. The PIR is similar to the MX9026/GRN-27 FFM in that it can only detect the contribution of the in-phase component of the SBO signal arriving at the monitor site. A means of simultaneously chart recording DDM outputs from both the VFFM units and from the PIR was essential. A DDM output was not directly available from the PIR unit. A buffer amplifier module was designed and built in order to interface between the PIR output and the chart recorder input in order to avoid loading down the PIR DDM meter as a result of a direct connection. Figure 4-1 depicts the circuit contained in the buffer amplifier module. The test set up used to obtain chart recording data from the PIR is shown in Figure 4-2.

4.4 ILS LOCALIZER SCATTERED SIGNAL SIMULATOR

In order to fully demonstrate the technique of quadrature detection a means of introducing a signal representative of a scattered SBO signal was required. Since the Monitor Precision Calibrator did not have a SBO output it could not serve its intended purpose entirely. What was needed was a test set-up which could generate and combine two signals; (1) the signal format of the localizer direct radiation pattern (CSB), and (2) a signal representative of SBO localizer energy such as would be re-radiated from a scatterer. In addition to simulating these described signals the signal levels had to be in the magnitude range of those which would be experienced

TABLE 4-4.
PIR TYPE FA-9392 DDM OUTPUT VS. MONITOR PRECISION CALIBRATOR INPUT

MONITOR PRECISION CALIBRATION DDM DISPLAY		PORTABLE ILS RECEIVER DDM DISPLAY	
Predominant 90 HZ	Predominant 150 HZ	90 HZ	150 HZ
.000	.000	.002 (150)	.002 (150)
.005	.005	.002	.007
.010	.010	.008	.012
.015	.015	.013	.018
.020	.020	.018	.023
.030	.030	.027	.033
.040	.040	.037	.044
.050	.050	.046	.055
.075	.075	.065	.082
.100	.100	.089	.112
.125	.125	.110	.142
.150	.150	.130	.170
.200	.200	.165	.235

Frequency: 111.7 MHZ
Input Level: -52 dBm
Date Measured: 2/24/82

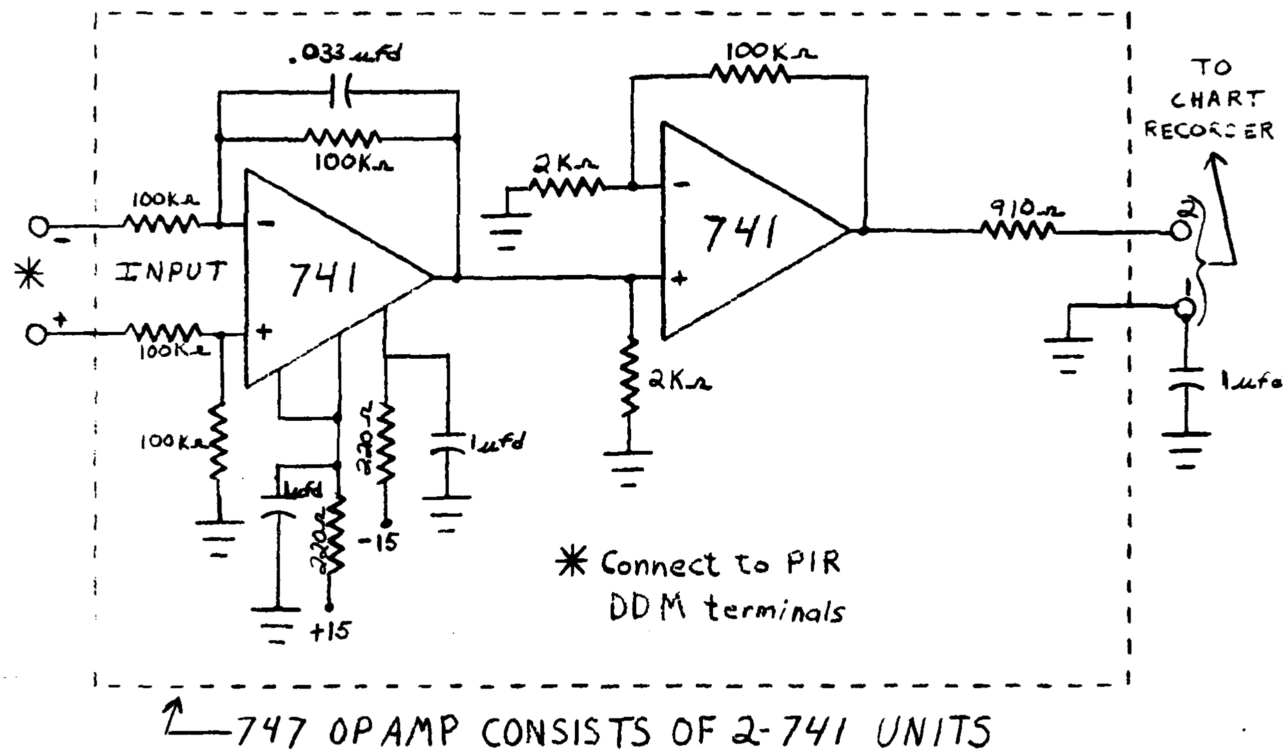


Figure 4-1. PIR Buffer Amplifier Schematic

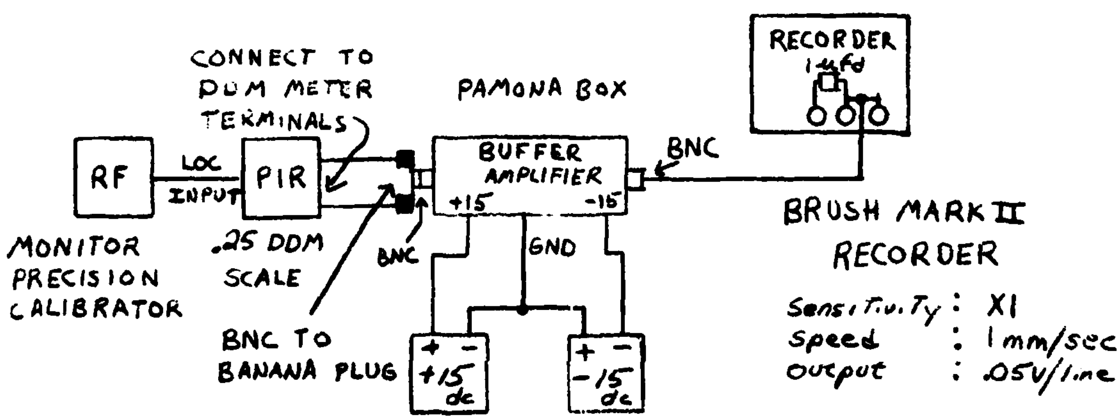


Figure 4-2. Test Setup for PIR Chart Recorder Connection

Figure 4-3. ILS Localizer Scattered Signal Simulator

at a far field monitor test site. To determine ty ical signal levels, RF level measurements were made at the proposed BWI test sites and found to be on the order of 350 microvolts for R/W 15R and 10 millivolts for R/W 10. With these parameters in mind a test set-up was designed and constructed using standard test equipment, RF components, connectors, and coax cable. Figure 4-3 shows the simulator layout. Phasing adjustments in the SBO line were provided by four 110 MHZ 90° trombone phase shifters which were loaned to the contractor from the FAA Techncial Center in Atlantic City, New Jersey. All of the rf subassemblies and cables were mounted on a 19 inch by 21 inch steel panel for convenient interface with the major test equipment and monitor units. A block diagram of the ILS localizer scattered signal simulator is shown in Figure 4-4.

4.4.1 FUNCTIONAL DESCRIPTION OF THE ILS LOCALIZER SCATTERED SIGNAL SIMULATOR

The function of this test set-up is to provide a test signal to the VFFM receiver and to the portable ILS receiver for bench testing and calibration purposes. It can be used over the entire localizer band.

A. Carrier Generation.

The carrier is generated by a synthesized VHF signal generator capable of at least + 10 dBm rf level output. No external or internal modulation of the signal generator is required. The required CSB and SBO signal formats are developed through the use of Merrimac PD-20-500 power dividers. These devices provide low insertion loss (typ. .5 dB), high isolation between outputs (min. 30 dB) and excellent phase and amplitude equality characteristics (within 1° and .1 dB respectively). As shown in the test set-up, Figure 4-4, the devices are used both in the forward mode as signal splitters and in the reverse mode as signal combiners.

B. Sideband Generation.

Carrier modulation is achieved through the use of double balanced mixers which are used to mix the carrier and a local oscillator input. The rf input signal to mixer No. 1 (L Port) is double sideband modulated by a lower frequency signal (90 HZ) applied to the I port. The mixer output (R port) contains the carrier signal and the ± 90 HZ sideband signals. Mixer No. 2 operates exactly the same way but with 150 HZ signal applied to the I port. The local oscillator signals were derived from Monsanto 3100A Frequency Synthesizers which are externally synched to a 1 MHZ source in order to keep the relative audio phasing of the 90 HZ and 150 HZ tones in-phase lock. The modulation level is controlled by adjusting the amplitude level of the synthesizers.

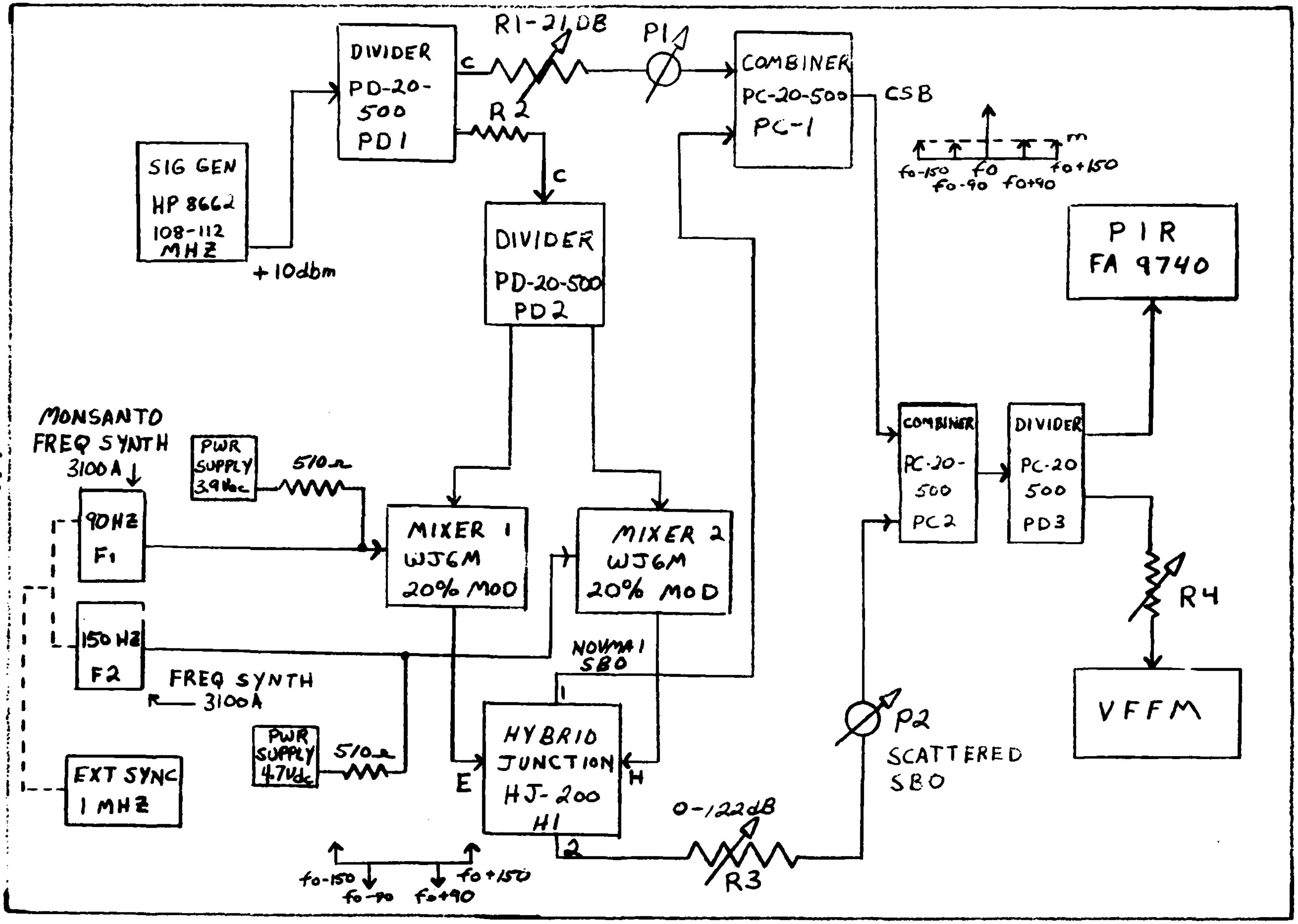
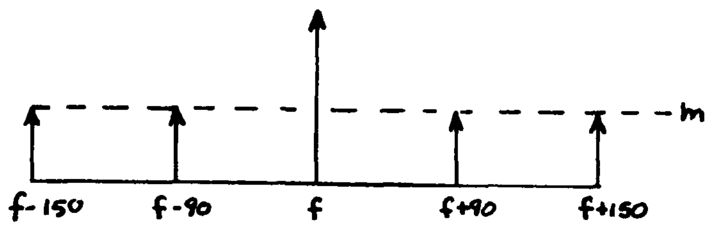


Figure 4-4. ILS Localizer Scattered Signal Simulator for Static Targets

C. Derivation of the C+SB Signal.

The CSB signal is representative of what exists at a far field monitor location in the absence of derrogations in the ideal case. The localizer direct signal contains only CSB and is given by:

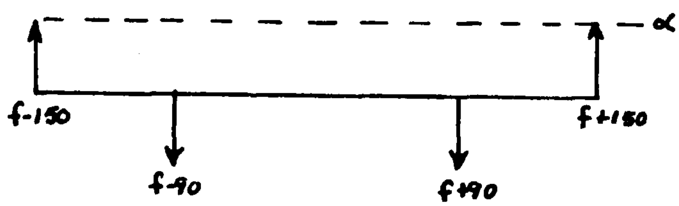


$$\text{CSB} \quad (1 + m\ \text{SIN}\ f_{150}\ t + M\ \text{SIN}\ f_{90}\ t)\ \text{SIN}\ wt$$

In order to simulate this signal format a sum and difference hybrid (H1) was used. This device has the property that simultaneous application of signals to both the H port and E ports results in their vector addition at port 1 and vector subtraction at port 2. The phase balance of H1 is 0°+1° with sum port (H port) feed and 180°±1° with difference (E port) feed. The CSB signal is derived from port 1 where it is routed to PC1 and combined with the carrier only from PD1. Variable attenuator R1 is used to adjust the carrier level with respect to the sidebands. Phasor P1 consists of 2 - 90° line strechers to ensure that the carrier and SBO inputs are initially in-phase.

D. Derivation of SBO Signals.

In order to simulate the effect of a derogation, a signal representative of the SBO signal which can be varied in both amplitude and phase is generated. The signal format for the SBO signal is given by:



where: α = scattered amplitude
ϕ = scattered phase

$$\text{SBO} = \alpha(\text{SIN}\ f_{150}t - \text{SIN}\ f_{90}t)\ \text{SIN}\ (wt + \phi\ (t))$$

Figure 4-5 . Bench Test Setup for Localizer Scattered Signal Simulation

Output port 2 of H1 is a suppressed carrier (40 dB) SBO signal with 90 HZ and 150 HZ sideband signals of equal amplitude but 180° out of phase. This signal is routed through R3 which is a variable attenuator used to vary the SBO amplitude and phasor P2 which is used to vary the SBO phase. This signal is ultimately fed to PC2 where it is combined with the CSB signal for application to the monitor receivers.

4.4.2 OPERATION OF THE ILS LOCALIZER SCATTERED SIGNAL SIMULATOR USING MANUAL PHASE SHIFTERS

The CSB and SBO output signals of the simulator can be regarded as the sources of coherent signals having a constant amplitude and phase ratio between them. This condition simulates interference as would be found in an airport environment such as the presence of static or slowly moving objects in critical locations. In order to demonstrate the VFFM principal of operation the equipment was connected as shown in Figure 4-4.

A. Feed test signal to both the PIR and the VFFM.

B. Adjust R3 for full attenuation; scattered SBO signal dummied up.

C. Switch VFFM selector switch to Q only position. Adjust phasor P1 and attenuator R1 to minimize Q channel indication on DDM meter. This adjustment provides proper carrier to SBO phasing.

D. Vary Q-Adjust to zero out any quadrature component remaining.

E. Switch VFFM selector switch to I-only position. PIR and VFFM DDM indication should be the same. Adjust audio output amplitude of F1 and F2 to vary DDM output.

F. Restore audio adjustment for 0 DDM indication.

G. Introduce scattered SBO signal by reducing R1 attenuation. Take out enough attenuation to achieve at least .100 DDM.

H. Adjust phasor P2 with VFFM in I-only position. The PIR and VFFM DDM should vary with change in SBO phase. With VFFM in the I&Q position only the PIR DDM output should vary with change in-phase. The VFFM output should remain constant but the predominant frequency indicator lights will alternate each time the SBO vector rotates through quadrature. This test demonstrates the ability of the VFFM to measure both in-phase and quadrature components of a scattered signal.

I. Adjust phasor P2 until quadrature is achieved. This condition will be recognized when the 90 HZ and 150 HZ indicator lights on the VFFM are both flickering. Adjust attenuator R1. The PIR DDM output should remian constant and the VFFM DDM output should change with the magnitude of the SBO signal.

   This test demonstrates when an SBO scattered signal arrives in quadrature with the CSB signal, it is not detected by a monitor system which can only measure the in-phase component.

4.4.3 OPERATION OF THE ILS LOCALIZER SCATTERED SIGNAL SIMULATOR USING VOLTAGE VARIABLE PHASE SHIFTER

In order to demonstrate the ability of the VFFM system to receive and process scattered signals of a dynamic nature, such as might be induced by aircraft overflying the localizer, it was necessary to modify the simulator. This modification is shown in Figure 4-6. Phase shifter P2 was replaced with an electronic phase shifter whose phase can be rapidly varied with the application of an external d.c. voltage. This phase shifter was able to introduce up to 140° of phase shift at a rate corresponding to the sine wave output of the HP 203A function generator. Figure 4-7 illustrates the response of the voltage variable phase shifter which was used for this demonstration.

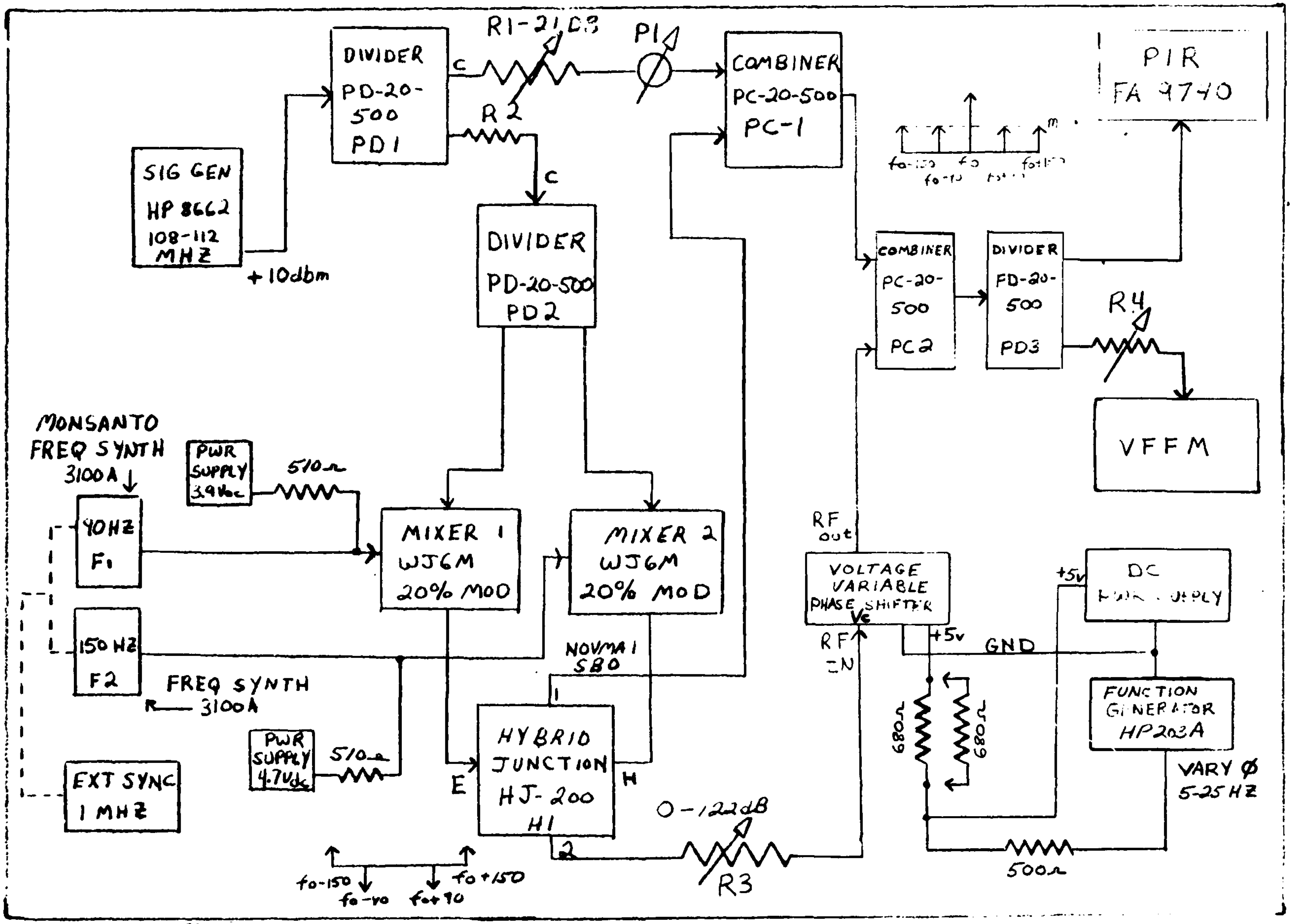


Figure 4-6. ILS Localizer Scattered Signal Simulator Test Setup for Moving Targets

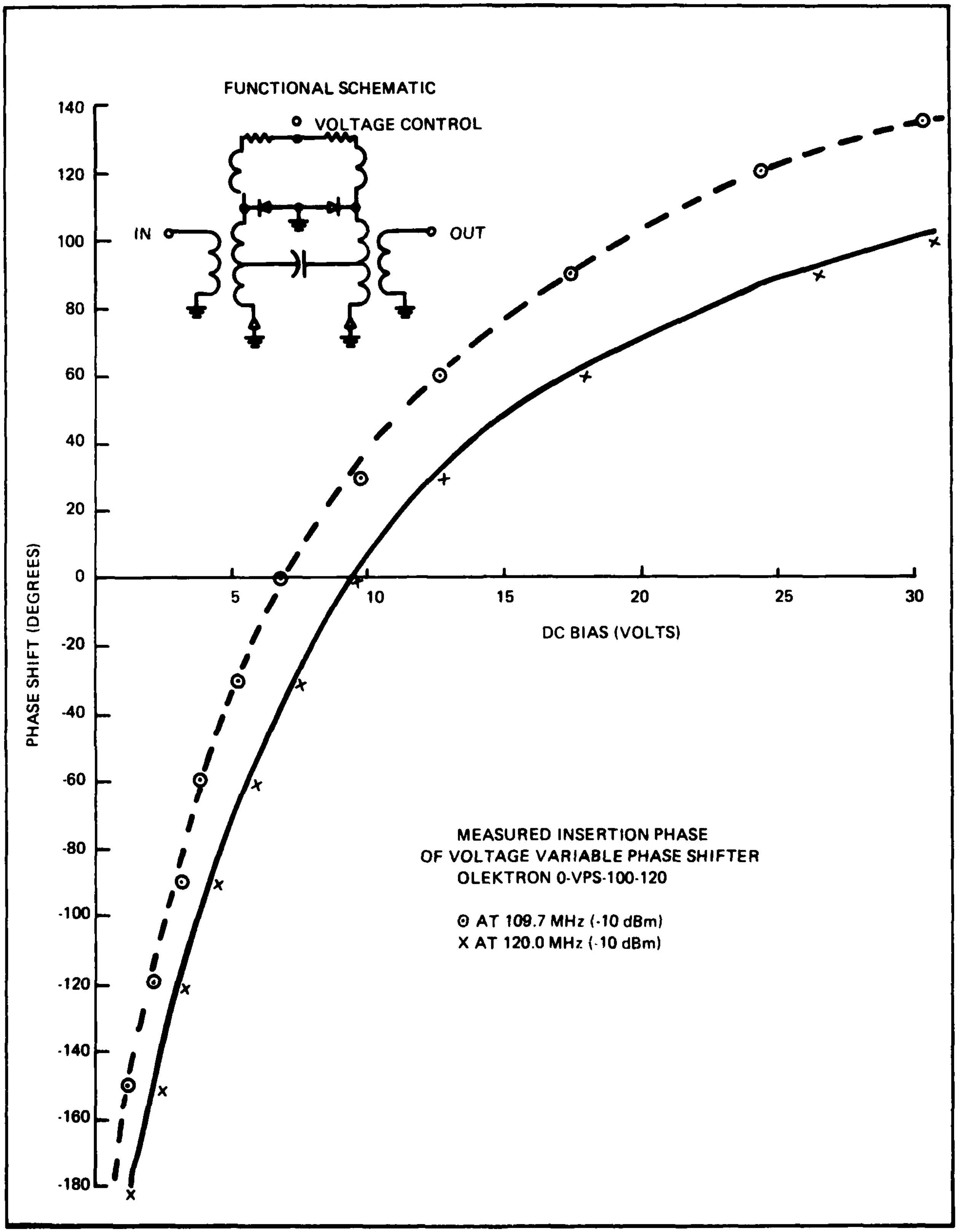


Figure 4-7. Phase Shift of Voltage Variable Phase Shifter at 109.7 MHz

5.0 FIELD TESTING

5.1 GENERAL

Field testing of the VFFM was conducted at BWI Airport, Baltimore, Maryland, and at the FAA Technical Center in Atlantic City, New Jersey.

5.2 BWI AIRPORT FIELD TESTS

BWI Airport was selected as a test site primarily because of its proximity to the contractor's plant (Westinghouse has its own taxiiway leading into the airport complex). The layout plan of BWI Airport is shown in Figure 5-1. However, in addition to the convenience which this provided, BWI has four ILS equipped runways 10/28 and 15R/33L, and a variety of localizer configurations. Initially, three test sites were proposed to be utilized at BWI. These test sites are shown in Figure 5-2 and 5-3. However, test site 'B' was not employed except for field strength measurements. Field testing began at BWI in June of 1981 and continued through December of 1981.

5.2.1 BWI R/W 10 FIELD TESTING - TEST SITE 'A'

Runway 10 is a CAT II ILS runway which is instrumented with a dual frequency AN-GRN/27 localizer system and an MX 9026-GRN/27 Far Field Monitor System. The existing monitor antenna is located approximately 1000 feet from the runway threshold and offset approximately five feet south from the R/W 10 centerline extended. The associated monitor equipment is colocated inside the inner marker beacon shelter. The VFFM test antenna was installed on a 20 foot triangular steel tower which was capable of being folded over when not in use. Figure 5-5 depicts the antenna/tower in the folded down mode. This antenna was a four element yagi which was supplied as GFE under the contract and is identical to the FFM antennas presently in use. The test antenna was located 50 feet inbound of the existing antenna and approximately two feet lower in elevation. DDM outputs from the two monitor channels of the existing FFM were not readily available for correlation purposes and access to the FFM equipment was restricted because of its commissioned status. The PIR was used extensively for comparative measurements. Both the PIR and the VFFM were fed simultaneously from the test antenna. Signal phase and amplitude equality to each receiver were assured through the use of a two-way power divider. The test equipment was rack mounted inside of the contractor's test vehicle. The test equipment configuration in the test van is shown in Figure 5-4. Initial measurements were made of the carrier signal strength level at the test site. The rf level meter reading was 67 which corresponds to approximately 10 millivolts input signal level as indicated in Figure 5-6. This provided approximately a seven millivolt input level to the PIR and the VFFM units after signal splitting. Excellent PIR and VFFM I-channel DDM output correlation existed as measured with both transmitters No. 1 and No. 2 radiating; however, the VFFM Q-channel output displayed a large quadrature output which was of a static nature and obviously not attributable to multipath interference. This was confirmed when the

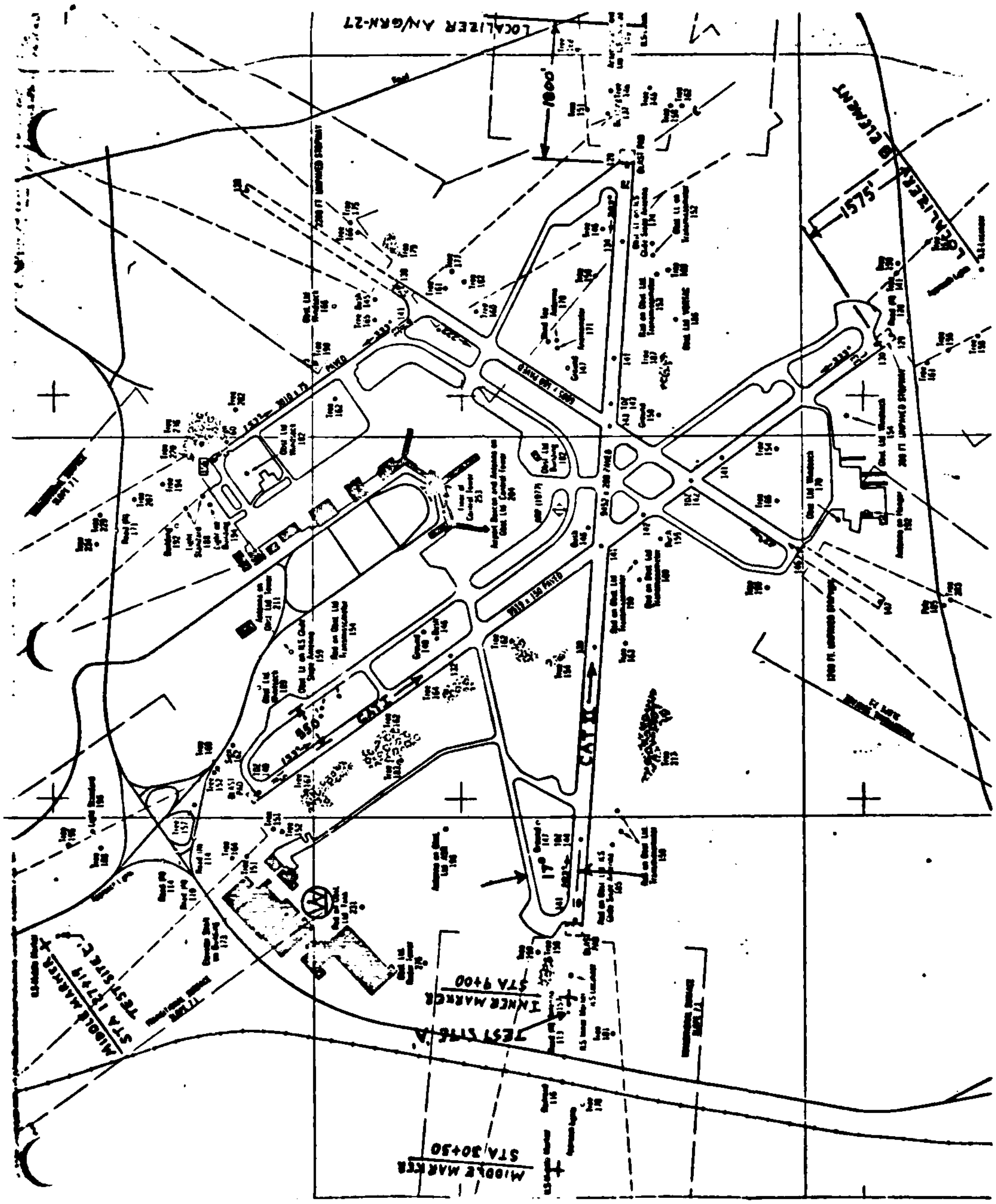
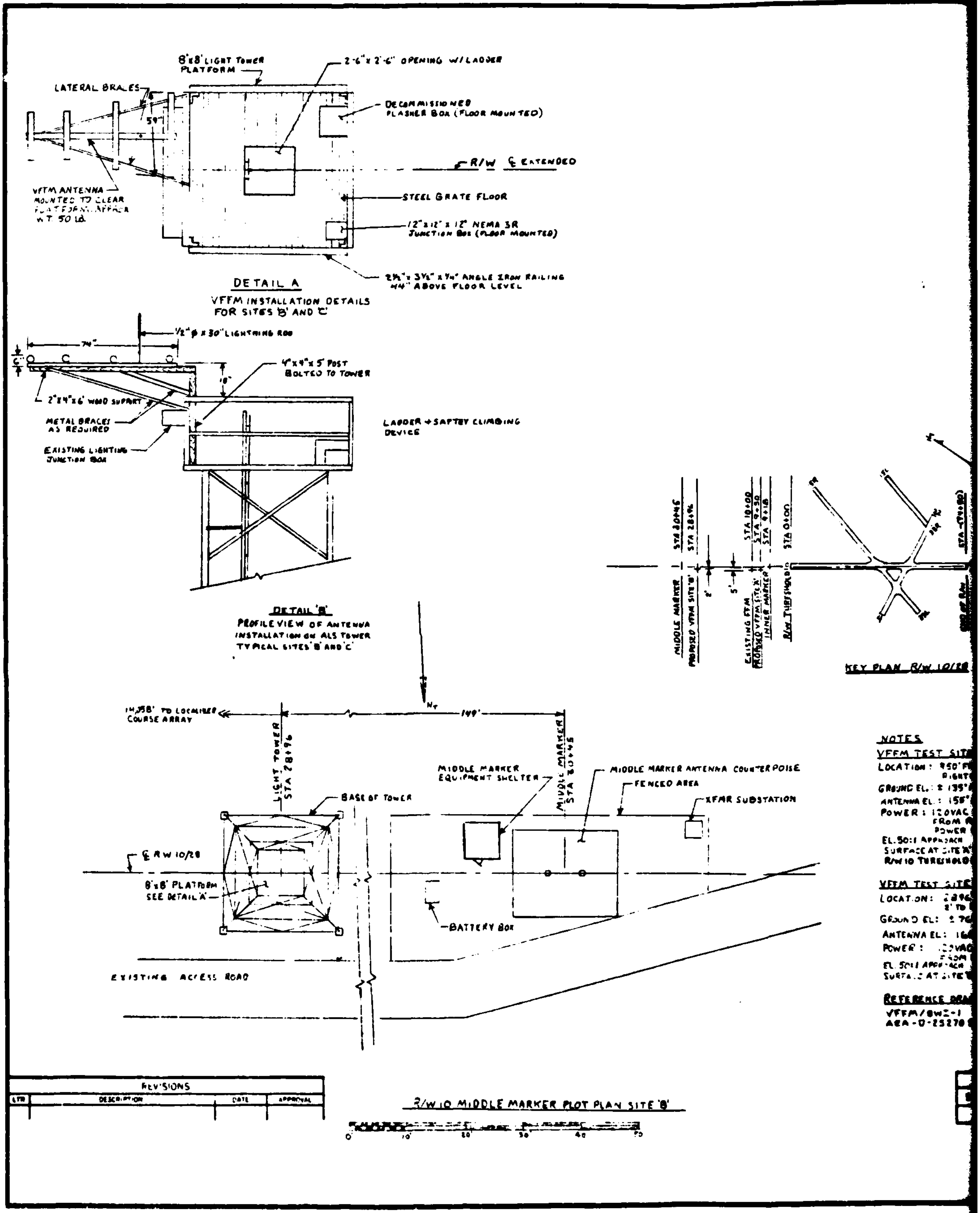
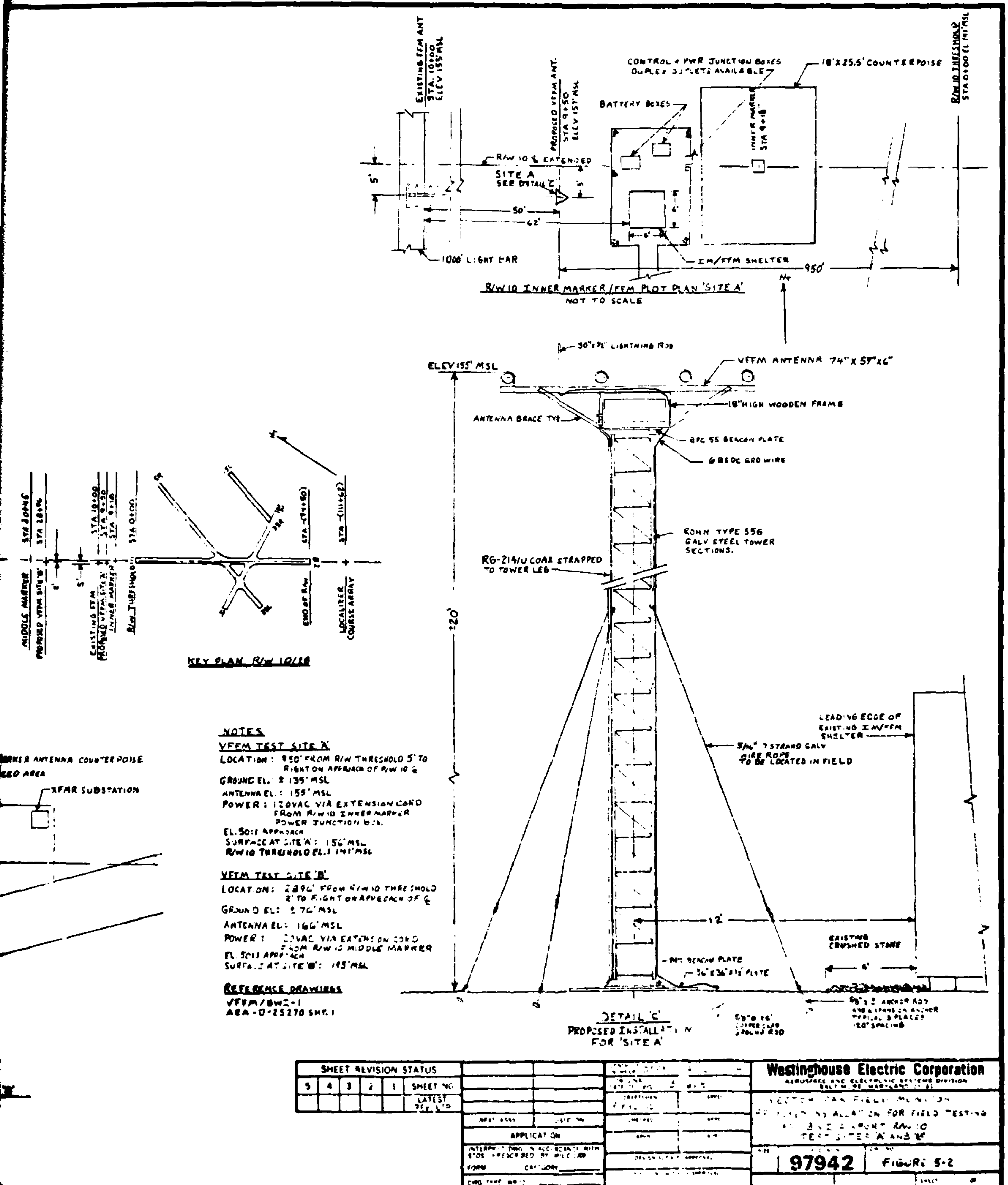
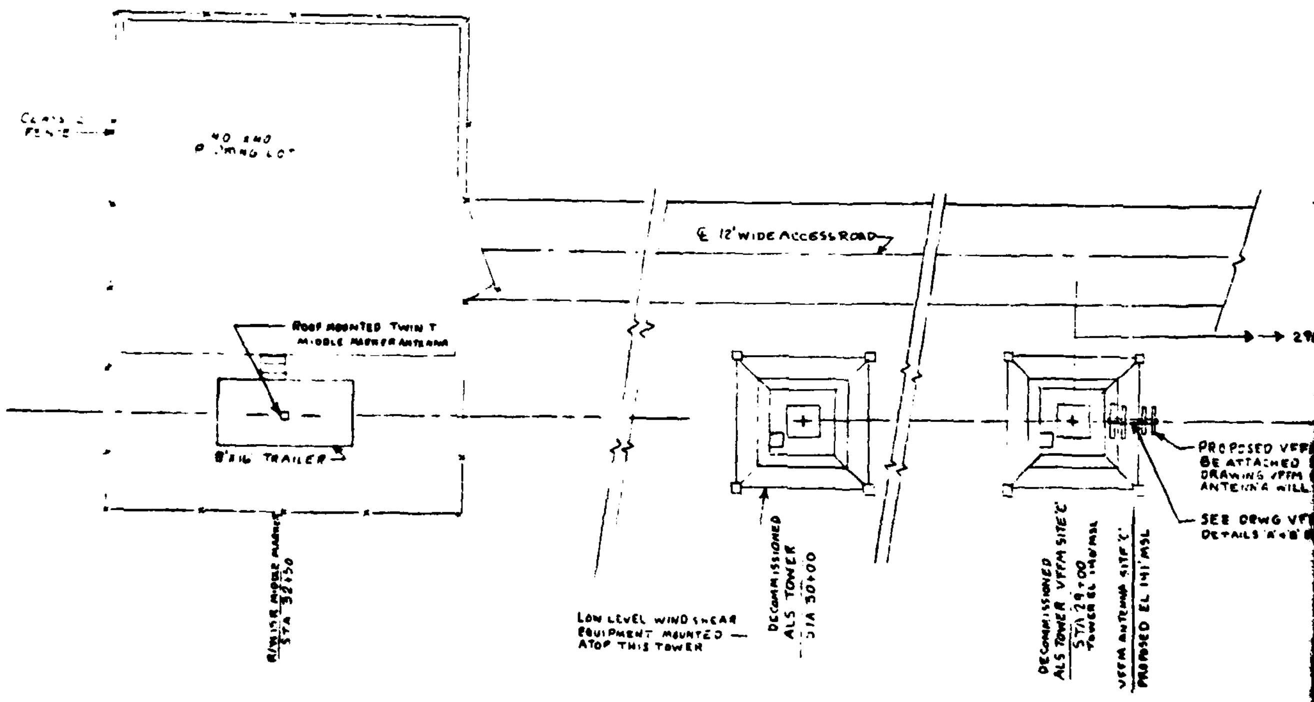


Figure 5-1. BWI Airport Layout Plan

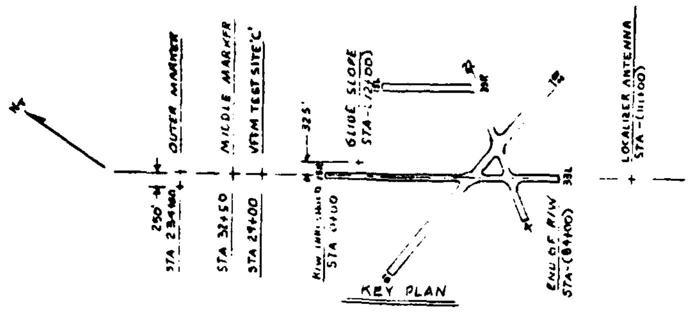

8'x8' LIGHT TOWER PLATFORM
2'-6" x 2'-6" OPENING W/LADDER
LATERAL BRACES
DECOMMISSIONED FLASHER BOX (FLOOR MOUNTED)
R/W ℄ EXTENDED
VFFM ANTENNA MOUNTED TO CLEAR
STEEL GRATE FLOOR
12" x 12" x 12" NEMA 3R JUNCTION BOX (FLOOR MOUNTED)
ABOVE FLOOR LEVEL
DETAIL A
VFFM INSTALLATION DETAILS FOR SITES 'B' AND 'C'
1/2" ⌀ x 30" LIGHTNING ROD
4"x4"x5' POST BOLTED TO TOWER
2"x4"x6' WOOD SUPPORT
METAL BRACES AS REQUIRED
LADDER + SAFETY CLIMBING DEVICE
EXISTING LIGHTING JUNCTION BOX
DETAIL 'B'
PROFILE VIEW OF ANTENNA INSTALLATION ON ALS TOWER TYPICAL SITES 'B' AND 'C'
MIDDLE MARKER
PROPOSED VFFM SITE 'B'
EXISTING FFM
PROPOSED VFFM SITE 'C'
INNER MARKER
R/W THRESHOLD
STA 0+00
KEY PLAN R/W 10/28
TO LOCALIZER COURSE ARRAY
149'
LIGHT TOWER STA 28+96
MIDDLE MARKER STA 30+45
MIDDLE MARKER EQUIPMENT SHELTER
MIDDLE MARKER ANTENNA COUNTERPOISE
FENCED AREA
XFMR SUBSTATION
BASE OF TOWER
℄ R W 10/28
8'x8' PLATFORM SEE DETAIL 'A'
BATTERY BOX
EXISTING ACCESS ROAD
NOTES
VFFM TEST SITE
LOCATION:
GROUND EL:
ANTENNA EL:
POWER: 120VAC
REFERENCE DRA
REVISIONS
LTR
DESCRIPTION
DATE
APPROVAL
R/W 10 MIDDLE MARKER PLOT PLAN SITE 'B'
0
10
20
30
40
50

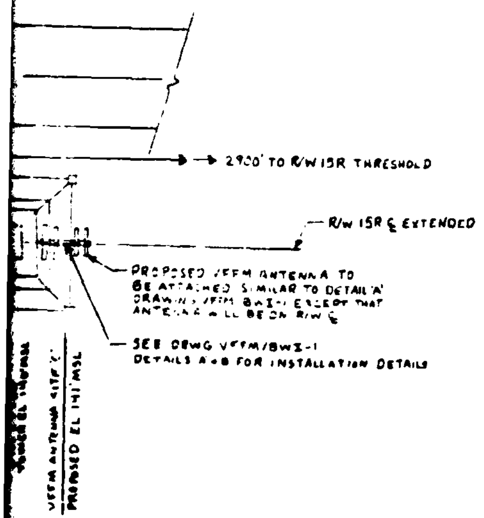


EXISTING FFM ANT STA. 10+00 ELEV 155' MSL
PROPOSED VFFM ANT. STA 9+50 ELEV 157' MSL
CONTROL + PWR JUNCTION BOXES DUPLEX OUTLETS AVAILABLE
18'X25.5' COUNTERPOISE
R/W 10 THRESHOLD STA 0+00 EL 141' MSL
BATTERY BOXES
INNER MARKER STA 9+18
R/W 10 ℄ EXTENDED
SITE A SEE DETAIL 'C'
50'
62'
1000' LIGHT BAR
IM/FFM SHELTER
950'
R/W 10 INNER MARKER/FFM PLOT PLAN 'SITE A'
NOT TO SCALE
30"X¾" LIGHTNING ROD
ELEV 155' MSL
VFFM ANTENNA 74" X 59" X 6"
18" HIGH WOODEN FRAME
ANTENNA BRACE TYP.
ROHN TYPE 556 GALV STEEL TOWER SECTIONS.
RG-214/U COAX STRAPPED TO TOWER LEG
KEY PLAN R/W 10/28
MIDDLE MARKER
PROPOSED VFFM SITE 'B'
STA 30+46
STA 28+96
EXISTING FFM
PROPOSED VFFM SITE 'A'
INNER MARKER
STA 10+00
STA 9+50
STA 9+18
R/W THRESHOLD
STA 0+00
END OF R/W
LOCALIZER COURSE ARRAY
LEADING EDGE OF EXISTING IM/FFM SHELTER
5/16" 7 STRAND GALV WIRE ROPE TO BE LOCATED IN FIELD
120'
12'
EXISTING CRUSHED STONE
NOTES
VFFM TEST SITE 'A'
LOCATION: 950' FROM R/W THRESHOLD 5' TO RIGHT ON APPROACH OF R/W 10 ℄
GROUND EL.: ± 135' MSL
ANTENNA EL.: 155' MSL
POWER: 120VAC VIA EXTENSION CORD FROM R/W 10 INNER MARKER POWER JUNCTION BOX.
R/W 10 THRESHOLD EL.± 141' MSL
VFFM TEST SITE 'B'
ANTENNA EL: 166' MSL
POWER: 120VAC VIA EXTENSION CORD FROM R/W 10 MIDDLE MARKER
REFERENCE DRAWINGS
XFMR SUBSTATION
DETAIL 'C'
PROPOSED INSTALLATION FOR 'SITE A'
SHEET REVISION STATUS
SHEET NO.
LATEST REV. LTR
APPLICATION
Westinghouse Electric Corporation
AEROSPACE AND ELECTRONIC SYSTEMS DIVISION
97942
FIGURE 5-2



REVISIONS			
LTR	DESCRIPTION	DATE	APPROVAL





REFERENCE DRAWINGS

VFFM/BWI-1
DCA-D-309
1-E-13910 SHTS 1&2

NOTES

VFFM TEST SITE 'C'

LOCATION : ON R/W 15R ℄ EXTENDED 2900' FROM R/W THRESHOLD

GROUND EL : ± 56.5' MSL

ANTENNA EL. : 14..0' MSL

POWER : 120VAC 60HZ VIA EXTENSION CORD FROM LLWS TOWER

EL 50:1 APPROACH SURFACE AT SITE C : 195' MSL

R/W 15R THRESHOLD EL : 148' MSL

SHEET REVISION STATUS					
5	4	3	2	1	SHEET NO
					LATEST REV. LTR

APPLICATION

Westinghouse Electric Corporation

AEROSPACE AND ELECTRONIC SYSTEMS DIVISION
BALTIMORE MARYLAND

VECTOR FAN FIELD MONITOR
PROPOSED INSTALLATION FOR FIELD TESTING
AT BWI AIRPORT R/W 15R
TEST SITE 'C'

97942

FIGURE 5-3

2

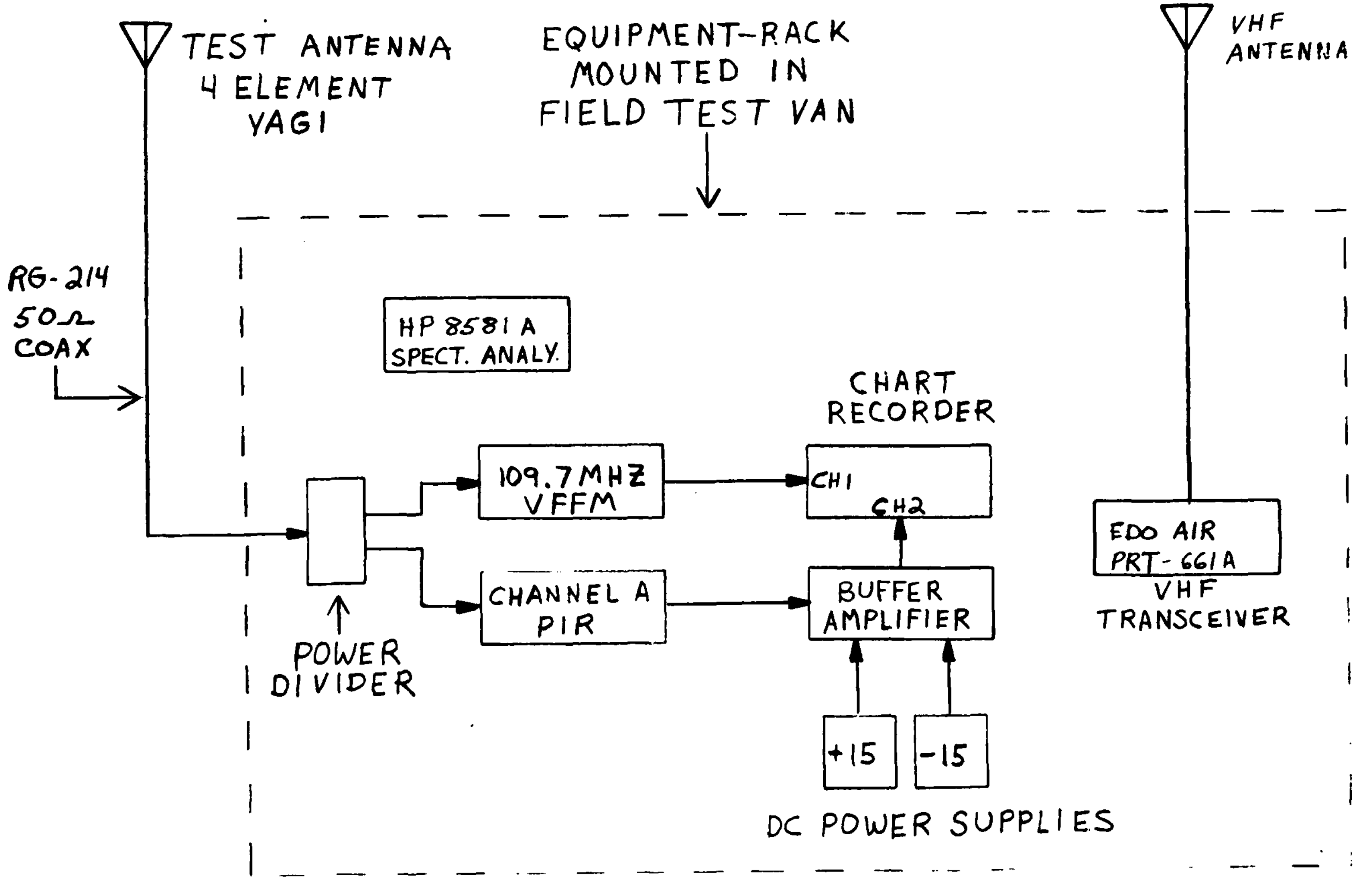


Figure 5-4. Field Test Setup for BWI R/W 10 Test Site 'A'

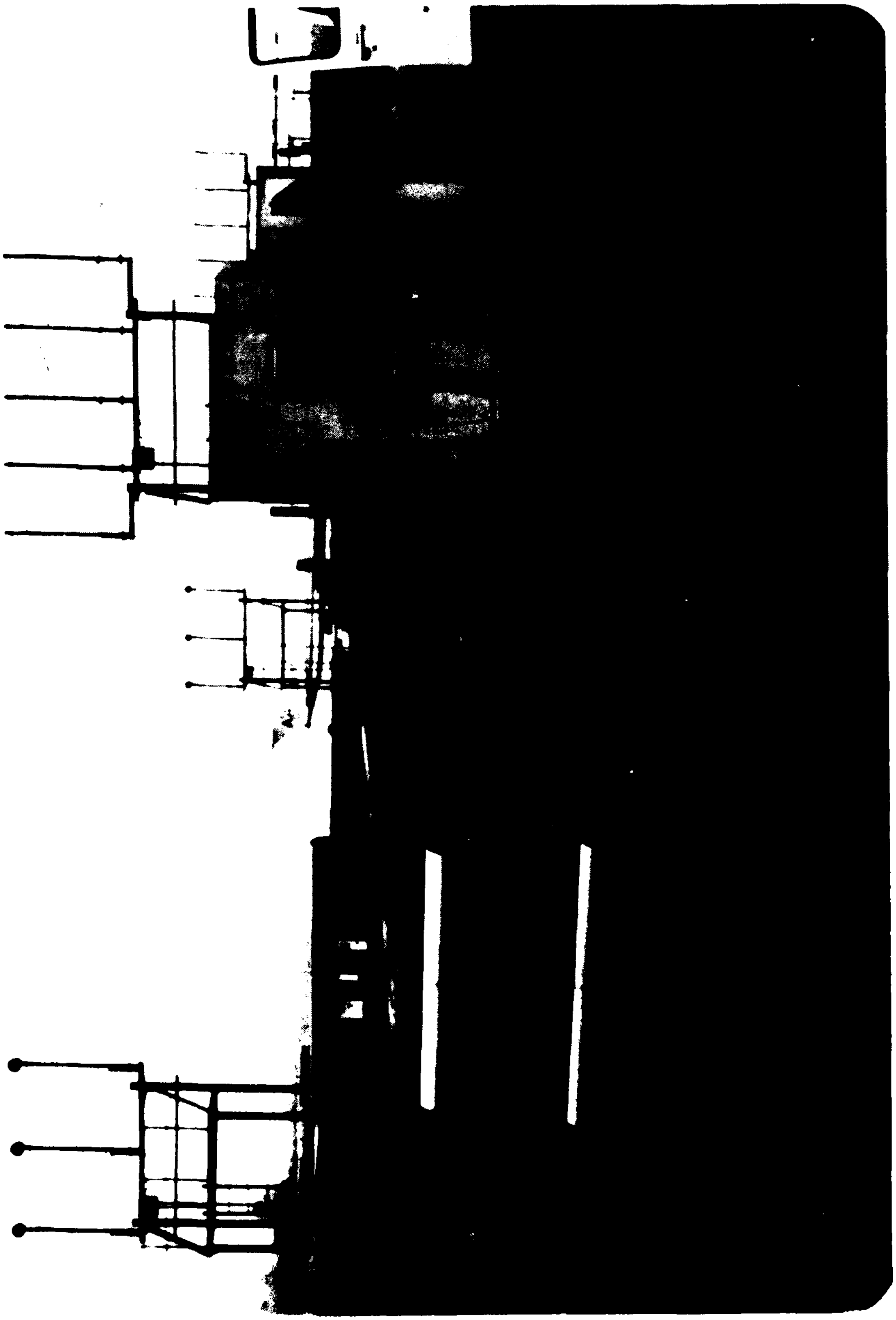


Figure 5-5. Test Site 'A' Antenna/Tower

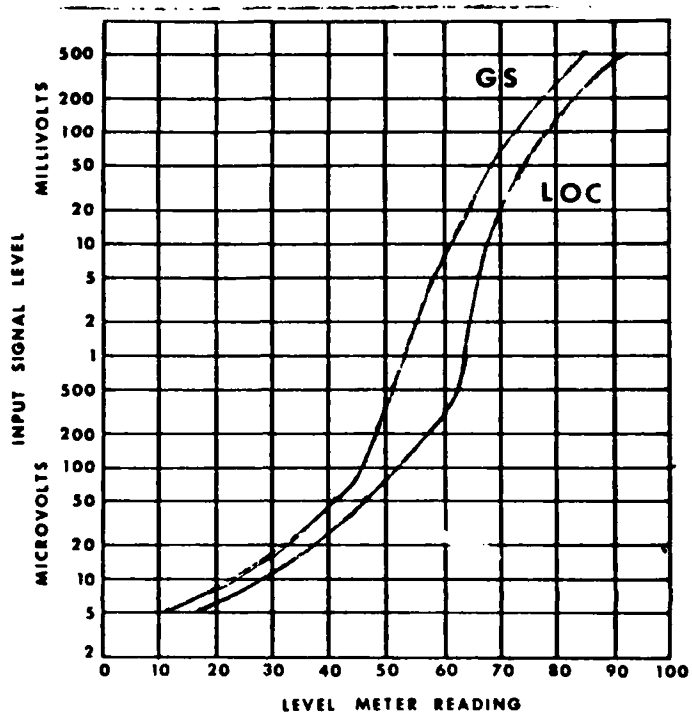


Figure 5-6. PIR Type 9740 S/N 1096
RF Level Calibration Curve

condition persisted with the transmitter SBO output dummied up. Measurements on a spectrum analyzer displayed sideband amplitude imbalance at the test site and led to the decision to measure the CSB output of the localizer course signal directly at the transmitter. Table 5-1 lists the data for all four BWI localizer transmitters as measured at the transmitter CSB output. Although only runways 10 and 15R were designated test sites, data on all four localizers was valuable in determining the extent of the audio signal misphasing problem. As can be seen from the data, I channel and PIR outputs display satisfactory agreement. The Q-channel output varied from as low as 7 microamps for R/W 15R Tx. No. 2 to as much as 150 microamps for R/W 28 Tx. No. 1. The cause of this quadrature output and the solution are described fully in paragraph 5.4. This condition led to the decision to compensate for the localizer quadrature output within the VFFM equipment.

During the period that the VFFM signal processor was being modified to provide a quadrature offset adjustment, field testing continued on R/W 10. A fixed offset was programmed into the microprocessor which corresponded to the amount of quadrature component as measured at the transmitter course CSB output. Measurements were made to determine the stability of the Q-channel output as measured at the transmitter on September 29, 1981. During a two-hour period transmitter No. 2, which was fully warmed up, had a Q-channel output of 32 microamps with excursions not exceeding ±3 microamps. Tx. No. 1, which was brought up cold, measured a Q-output of 45 microamps ±5 over a 20-minute period.

Field testing efforts on R/W 10 were limited by localizer system availability. Erection of the test antenna was obviously not permitted during CAT II operations and system radiating time was much less than on the opposite runway end. When field test data was taken, efforts were concentrated primarily on aircraft ground movements; however, disturbances created by flying aircraft such as the helicopter overflight trace as shown in Figure 5-7 were recorded. This illustrates the envelope detection technique of the I and Q channels versus the I channel only oscillatory response of the PIR. Figure 5-7 also illustrates a problem with the VFFM receiver created by flying aircraft either landing or taking off regarding loss of lock of the carrier signal. This receiver sensitivity problem was definitly related to both the size and speed of the aircraft involved. A small single engine aircraft would not perturbate the input signal strength enough for the VFFM to become unlocked; while a large four engine jet aircraft passing through the transmitter/receiver line of sight would almost always create a loss-of-lock up condition. This condition is believed to be related to the phase lock loop holdtime and is more fully described in Paragraph 3.4.3.

5.2.2 BWI R/W 15R FIELD TESTING - TEST SITE 'C"

R/W 15R is a 9519 foot long CAT I ILS runway. The localizer system is a single frequency dual transmitter TV-30, located 1575 feet from the stop end of the runway. The test site for the VFFM was initially located on the approach light tower located 2900 feet from the R/W 15R threshold but was later relocated to the approach light tower 3,000 feet from the threshold. A six element triple driven yagi antenna was used for field testing. It was

TABLE 5-1. BWI AIRPORT LOCALIZER CSB OUTPUT DATA AS MEASURED AT TRANSMITTER

R/W	DATE MEASURED	TYPE SYSTEM	FREQ. (MHZ)	SPECTRUM ANALYZER MEASUREMENTS SIDEBAND LEVELS REL. TO CARRIER (dB)				TX NO. 1 PIR DDM	TX NO. 1 VFFM DDM			TX NO. 2 PIR DDM	TX NO. 2 VFFM DDM		
				150_L	90_L	90_U	150_U		I	Q	I + Q		I	Q	I + Q
28	6/16/81	AIL MECH MOD	109.700664	-18.1	-17.8	-18.6	-19.4	0	0	150	150	N/A		N/A	
15R	6/18/81	TV-30 SS MOD	111.699782	-19.6	-19.9	-19.9	-19.5	.008(150)	3.5 (150)	12 (90)	10 (150)	.008(150)	4 (150)	7 (90)	10 (150)
10	6/19/81	AN-GRN-27	109.706076	-19.5	-19.3	-19.3	-19.5	.001(90)	1 (90)	115 (150)	95 (90)	.001(90)	.5 (90)	80 (150)	50 (90)
33L	6/23/81	MARK IE	111.698924	-18.8	-19.2	-18.6	-18.1	.003(90)	1.5 (90)	150 (150)	125 (90)	N/A		N/A	

AD-A122 205 INSTRUMENT LANDING SYSTEM LOCALIZER VECTOR FAR FIELD MONITOR DEVELOPMENT..(U) WESTINGHOUSE DEFENSE AND ELECTRONIC SYSTEMS CENTER BALTIMORE M.. 2/2

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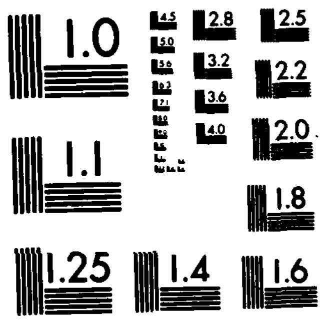
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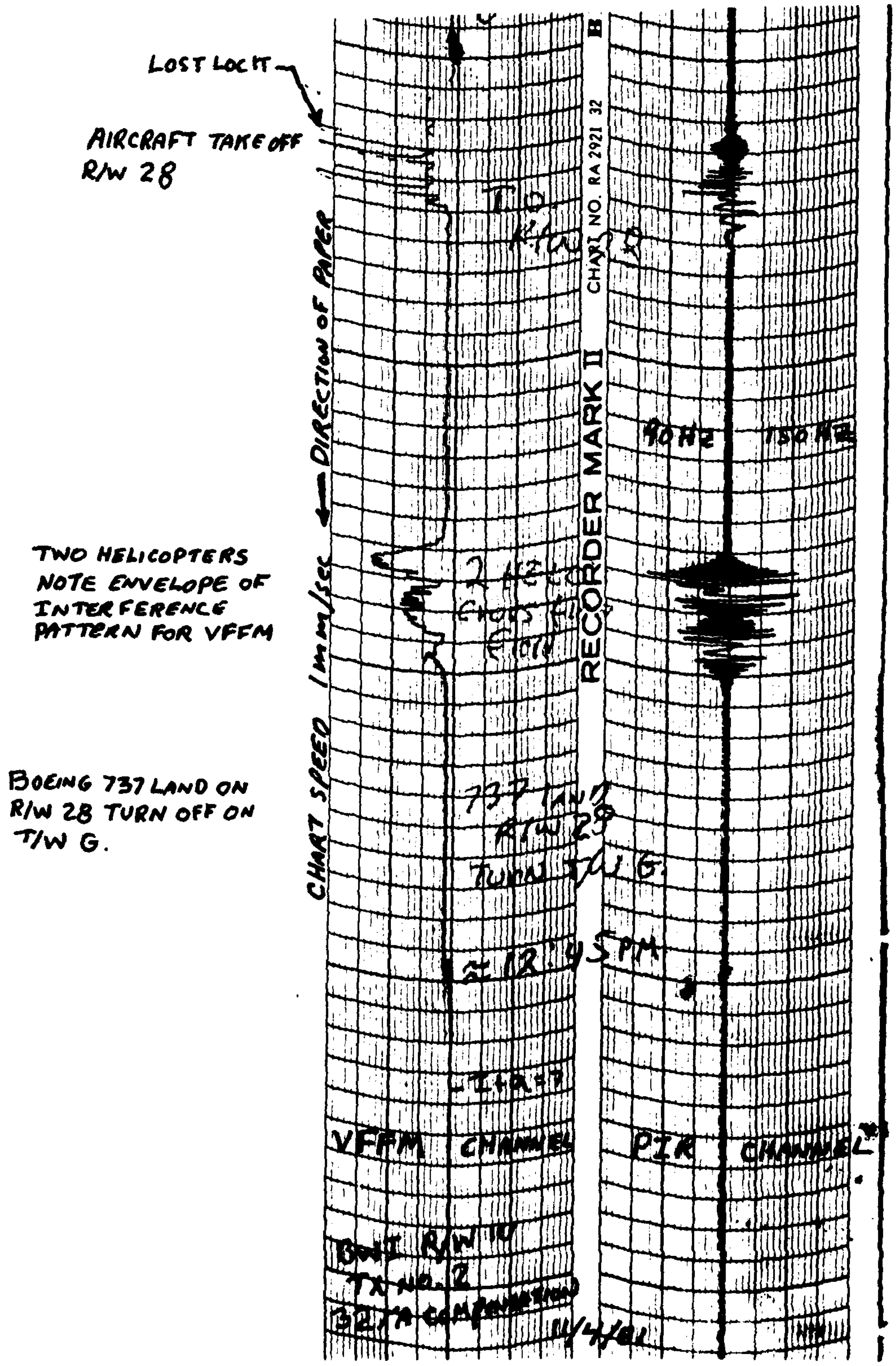


Figure 5-7. R/W 10 Test Site 'A' Field Test Data

attached to the top of the light tower at an elevation of 141 feet MSL. The distance from the localizer antenna to the VFFM test antenna was 14,100 feet. RF level at this site was measured at 55 on the PIR which corresponds to approximately 150 microvolts as shown in Figure 5-6. The taxiway layout for R/W 15R/33L was more typical than that which existed on R/W 10/28. A parallel taxiway with a 550 foot T/W centerline to R/W centerline displacement exists along most of the runway length. This site was more conducive to field testing than R/W 10 since the R/W 15R ILS system is in use during most BWI operations. An escort to the test site was not required since it was located outside of the airport restricted area. The detected quadrature output from the runway 15R localizer was low enough to permit field testing without using a fixed offset in the signal processor Q-channel input. The localizer transmitter which was on the air was identified by monitoring the character spacing of the R/W 15R localizer identification code as detected through the audio output of the PIR with a headset.

Monitor data on R/W 15R was obtained from various types of aircraft movement such as takeoffs and landings on the monitored ILS runway, takeoffs and landings on the intersecting runway (10/28), taxiing aircraft at the approach, midfield and rollout end of the monitored runway. In addition, disturbances caused by helicopters intercepting the localizer guidance signal were observed. The most significant data was related to taxiing and parked aircraft on TWY close-up "O". Figure 5-8 represents VFFM versus PIR chart recording data taken during the take-off from R/W 28 of a single engine aircraft. A DDM disturbance of approximately 15 microamps persisted for at least 13 seconds longer on the VFFM after the PIR response returned to normal. Figure 5-9 illustrates data obtained while two twin engine aircraft taxiied along T/W 'O' in preparation for takeoff on R/W 15R. Figure 5-10 contains a sample of a DDM disturbance believed to be created by a DC-9 aircraft taking off on R/W 28 and intersecting the monitored R/W 15R runway. R/W 10/28 intersects R/W 15R/33L at approximately a 48 degree angle with respect to the R/W 15R/33L centerline. A VHF mobile communications transceiver was used to monitor the ground control (121.9 MHz) and approach control (119.7 MHz) frequencies. The field testing effort required data correlation between aircraft/vehicle movement on the airfield and the monitor response as measured at the test site. This was accomplished via communications between the test equipment van and an observer located with full view of the test runway.

5.3 FAATC Field Tests

Field testing of the Vector Far Field Monitor at the FAATC in Atlantic City, NJ was conducted during a two-week period beginning on 5/10/82. The equipment was colocated within the existing R/W 13 FFM/MM equipment shelter. The R/W 13 localizer is a MARK III two frequency system operating on a course transmitter frequency of 109.1047 MHz. The localizer antenna consists of a course array, clearance array, and a parabolic reflector. The airport layout plan for the FAATC facility is shown in Figure 5-11. The three existing far field monitor antennas were used during the field testing effort. These antennas were the four element yagi's used with the MX-9026/GRN-27 FFM system. They were mounted on approximately 30 foot high wood poles which were located along the R/W 13 centerline extended and spaced 200 feet apart.

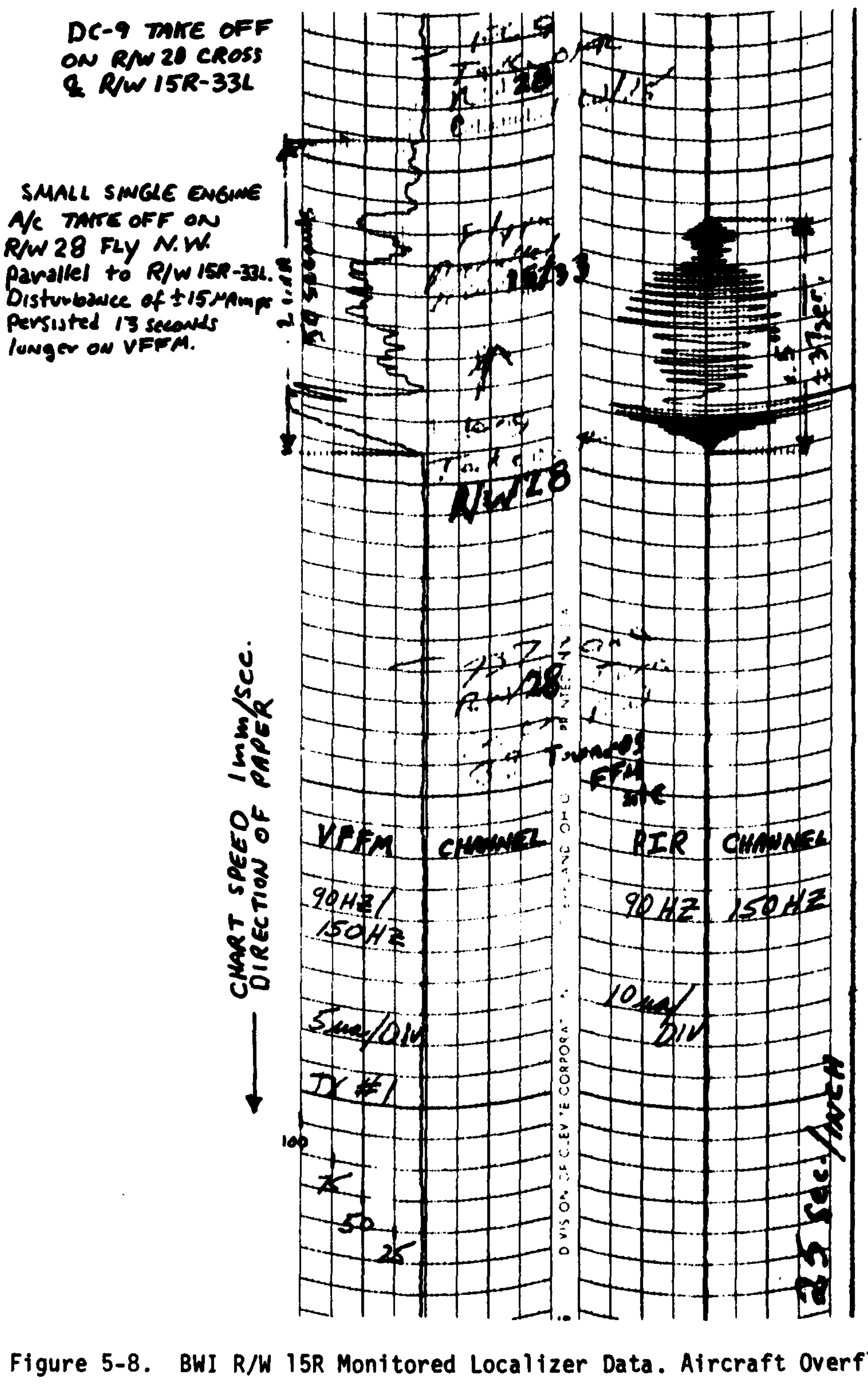


Figure 5-8. BWI R/W 15R Monitored Localizer Data. Aircraft Overflight

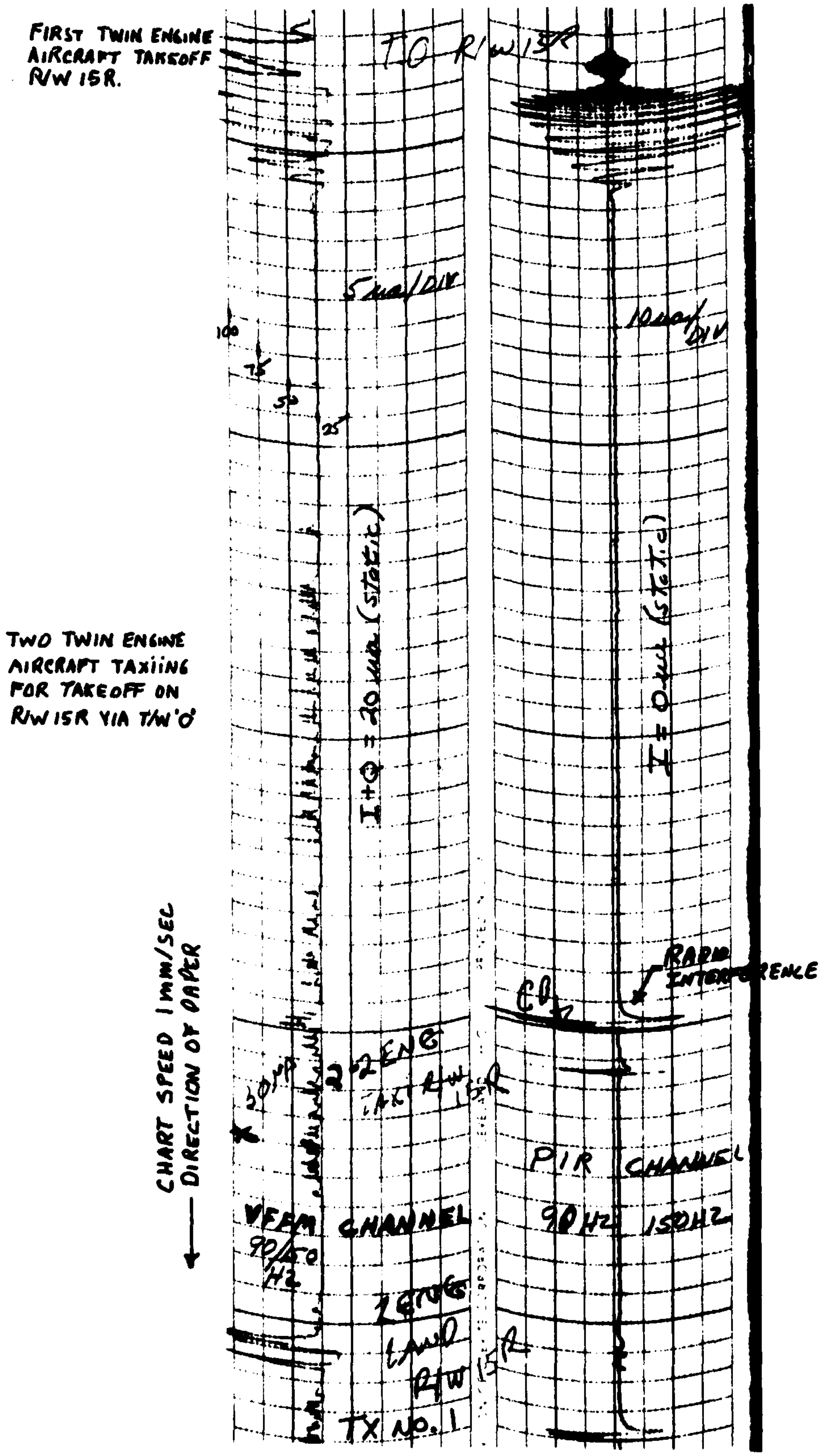


Figure 5-9. BWI R/W 15R Monitored Localizer Data. Aircraft Taxiing on T/W 'O' for Takeoff

DC-9 TAKE-OFF ON R/W 28. CROSSES ¢ R/W 15R-33L.

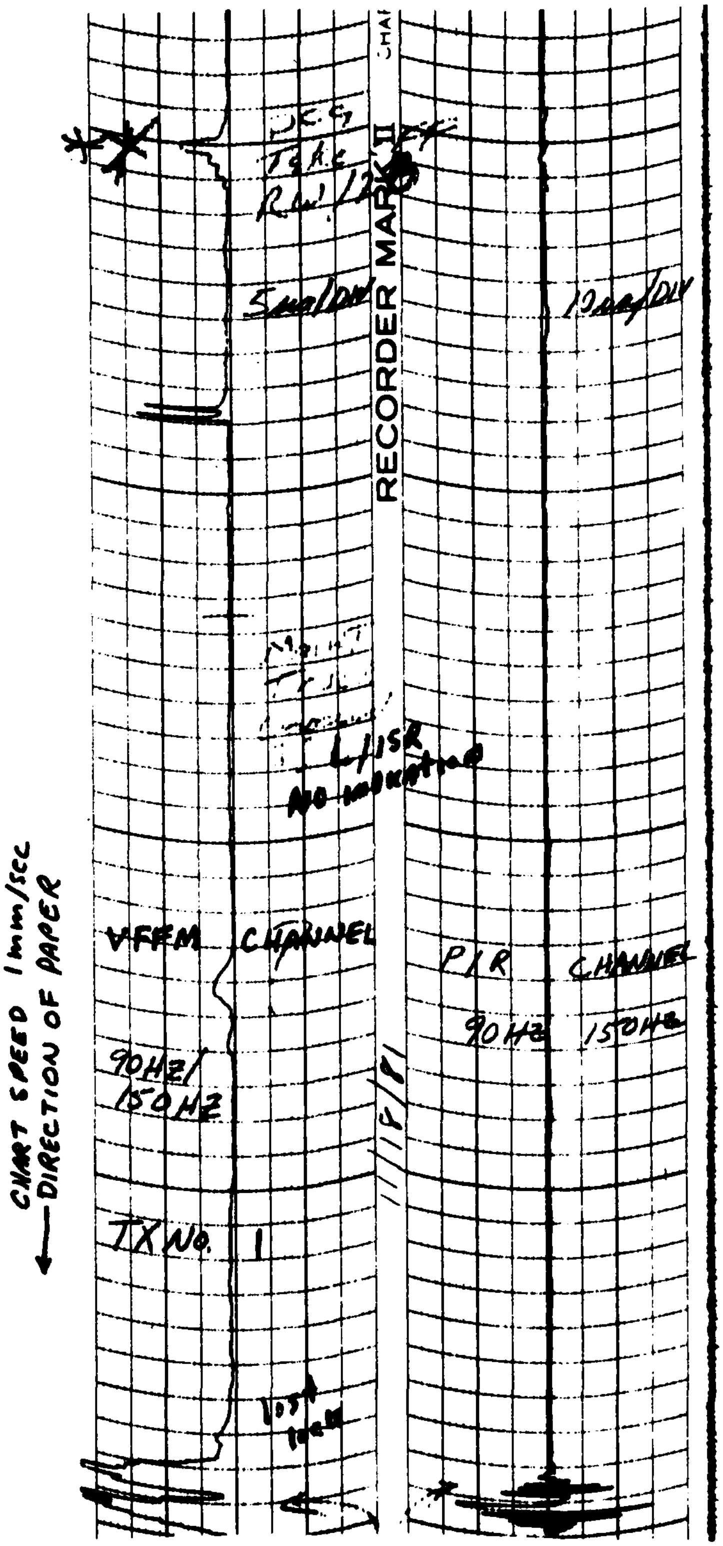
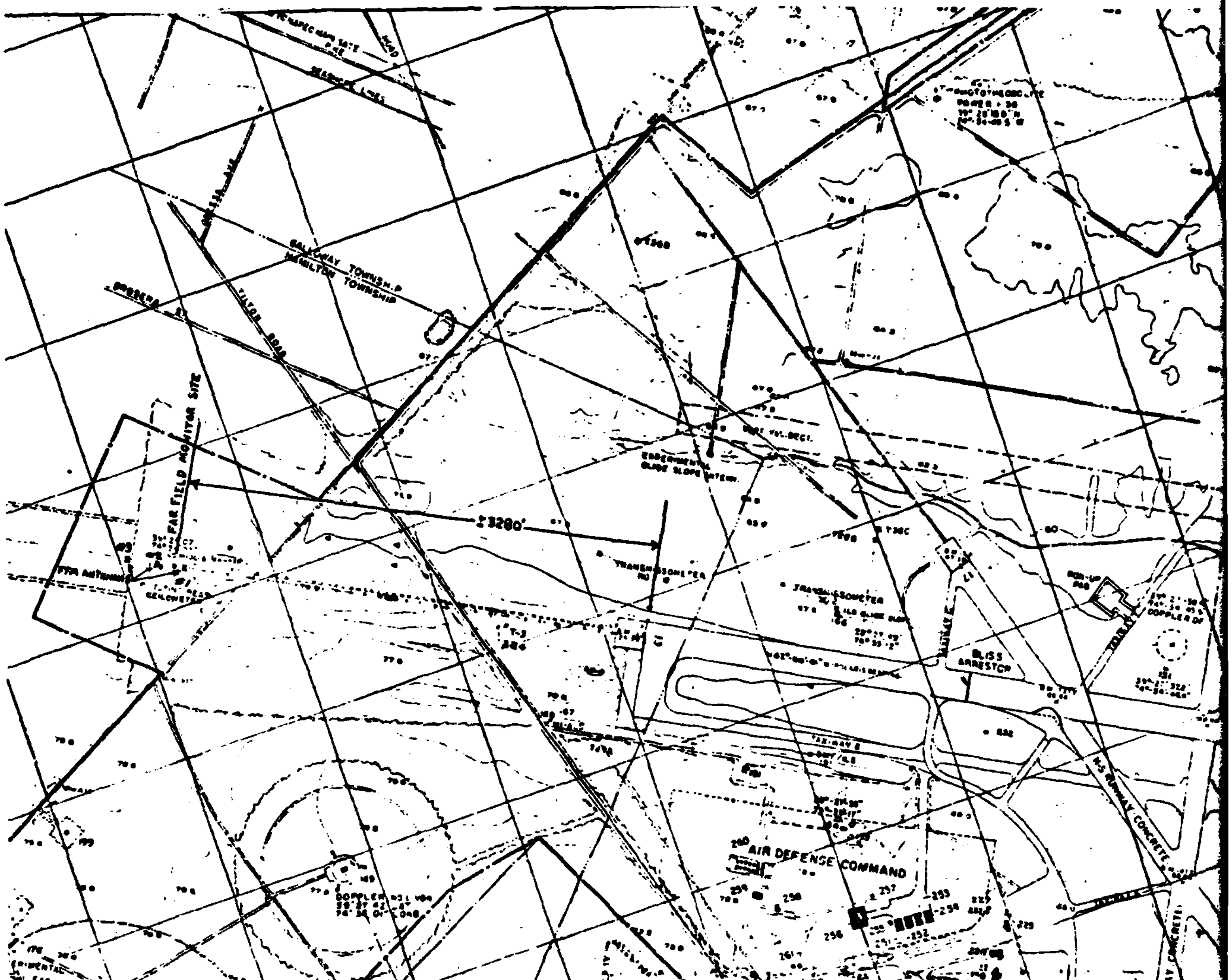


Figure 5-10. BWI R/W 15R Monitored Localizer Data. Aircraft Takeoff on Intersecting Runway.



FAR FIELD MONITOR SITE
GALLOWAY TOWNSHIP
HAMILTON TOWNSHIP
3280'
FAA ANTENNA
TRANSMISSOMETER
BLISS ARRESTOR
AIR DEFENSE COMMAND
ASDE TOWER
PRIVATE PROPERTY
RUNWAY CONCRETE

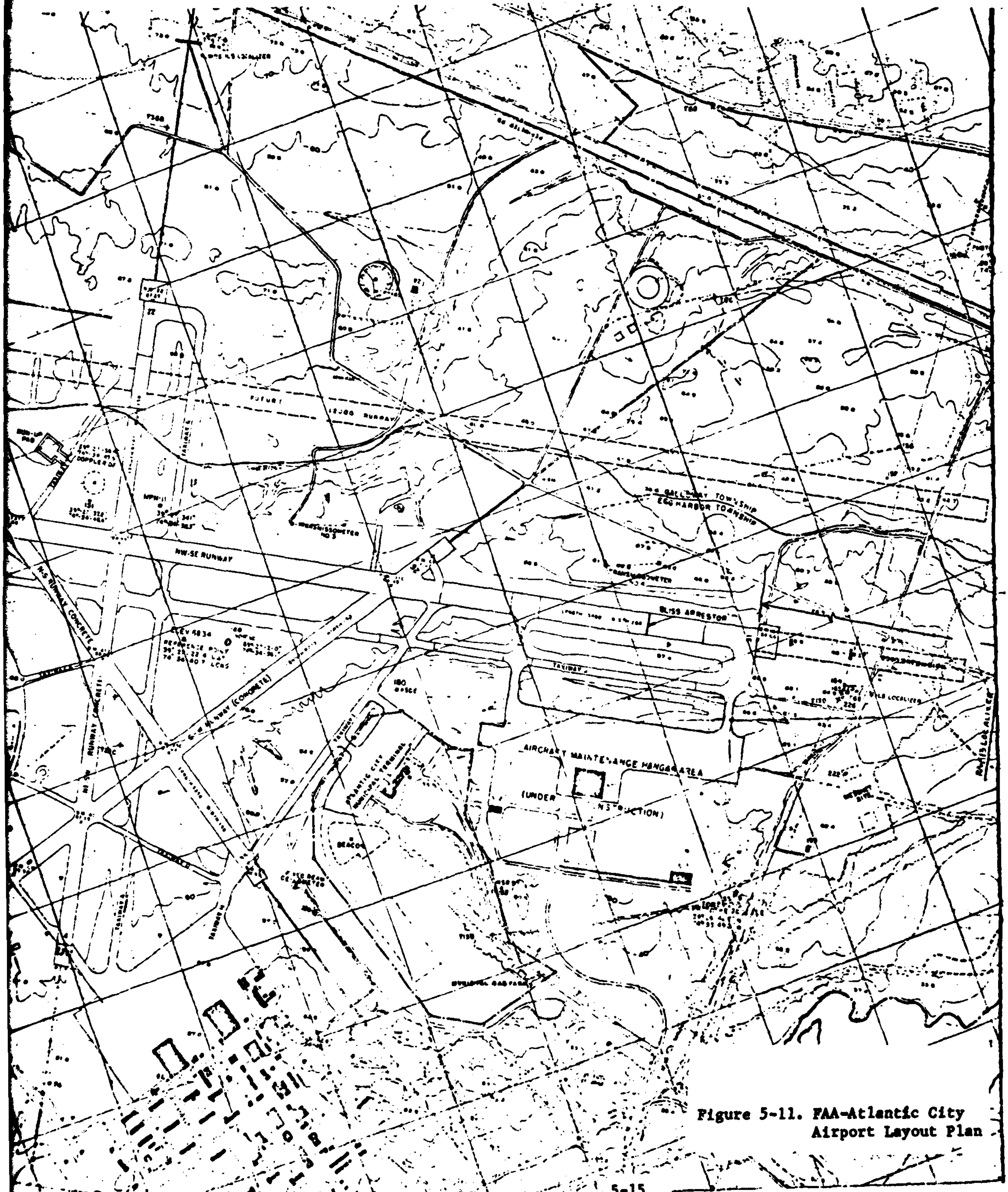


Figure 5-11. FAA-Atlantic City Airport Layout Plan

2

The three developed VFFM units S/Ns 001, 002 and 003 were used during the field testing effort; however, it was only possible to operate two units simultaneously since only two 109.1 MHz RF AMP/Local oscillators were built under the contract. Although the FAATC R/W 13 localizer system is a commissioned CAT I facility, traffic conditions allowed for a greater flexibility in terms of adjustments to the localizer transmitter system and system availability. Additionally, the three existing FFM antennas provided the potential for testing the effectiveness of the single point monitor far field monitor technique. The three VFFM units used during the FAATC field tests contained a built-in quadrature offset adjustment.

This capability was not available in time for use at the BWI Airport test sites.

5.3.1 FAATC LOCALIZER QUADRATURE OUTPUT MEASUREMENTS

Once the monitor units were installed at the test site, preliminary data was obtained relative to determining the incidental phase modulation of the localizer transmitter. This data was obtained both at the test site and at the transmitter. The results are shown in Table 5-2.

TABLE 5-2. FAATC TESTS TO DETERMINE Q-OFFSET ADJUSTMENT

TX	VFFM Location	I	Q	IaQ	SDM	FFM Antenna	Radiation Config.
		Microamps		S/N 002	Δ Mod		
1	at FFM	0	45	45	40	3	CSB + SBO
1	at FFM	0	45	46	40	3	CSB Only
1	at FFM	0	46	46	40	1	CSB Only
2	at FFM	0	42	42	37.5	1	CSB + SBO
2	at FFM	0	42	42	37.5	3	CSB + SBO
2	at FFM	5(150)	42	44	37.5	3	CSB Only
2	at FFM	5(150)	42	43.5	37.5	1	CSB Only
1	at Loc.	0	48	48	40	N/A	CSB Only
2	at Loc.	0	43	43	37.5	N/A	CSB Only

The results of these tests indicated that a quadrature offset equivalent to approximately 48/43 microamps for transmitters Nos. 1/2 respectively would be required in order to eliminate Q-channel signal caused by transmitter I_{PM}. During these tests, the clearance transmitters were cycled on and off without any change in VFFM output. A Q-channel stability test was performed on TX. No. 1 on 5/12/82 between the period of 5:30 to 10:10 PM. An rf pickup element was inserted into the course transmitter wattmeter body and the sampled rf signal was fed to the VFFM S/N 002 rf input. The measured Q output was chart recorded. Except for some receiver loss of lock problems which persisted for the first half hour of operation, the Q-signal as measured at the CSB output remained within three microamps. This was well within what can reasonably be expected in terms quadrature output stability.

5.3.2 R/W 13 LOCALIZER TRANSMITTER ADJUSTMENTS

Comparative field test data was obtained between two VFFM units, two existing FFM units, and the PIR readout while transmitter adjustments were made to cause CAT I and CAT II alarms. The results of this testing is shown in Table 5-3. Each of the VFFM units were connected to a separate antenna. Antenna No. 1 was approximately 3260 feet from the R/W 13 threshold with antenna No. 3 approximately 400 feet further out. The elevation and alignment of these antennas were essentially identical. Figure 5-12 shows the antenna alignment at the FAATC test site.

5.3.3 DESCRIPTION OF THE FAA'S DIGITAL RECORDING SYSTEM

In order to record sampled data from the VFFM units and the existing FFM units, the FAA's Remote Maintenance Monitor Group ACT-100L located at the FAATC provided invaluable assistance. A Remote Monitor Subsystem (RMS) previously designed and built by ACT-100L personnel for a different program was modified in order to provide a data collection package which had a one second data update rate for use during the VFFM test program.

A block diagram of the RMS as used during the VFFM field test is shown in Figure 5-13. The RMS had an eight-channel capability. Three of the channels were used to output the dc voltage levels corresponding to the existing FFM channels. Four channels were required to collect data from two of the VFFM units. These were dc voltage levels corresponding to the DDM and SDM outputs. The final channel was intended for inputting the PIR DDM signal; however, the PIR output voltage level was too high for the A/D board and was not used. In order to analyze the data which was recorded, it was necessary to translate the voltage levels outputted from the monitor to DDM. This was done by using the Precision Monitor Calibrator to feed a known DDM input signal to both the VFFM unit and an existing monitor unit simultaneously and measuring the dc voltage level output. The corresponding DDM levels/voltage levels for 150 Hz predominant signals is shown in Tables 5-4 and 5-5 lists resulting voltage levels for 90 Hz inputs from the PMC. In order to correlate monitor response data with cause of the disturbance, an observer was located in the ASDE tower with direct communications to the test site. A log was made of aircraft activity during the field tests. A sample output of the FAA's digital recording system is shown in Figure 5-14.

5.3.4 EXTERNALLY INDUCED FAULT TESTS

In order to determine if a signal scattering situation could cause a substantial DDM difference between the existing monitors, the PIR and the VFFM, an experiment was conducted to purposely disturb the localizer radiation pattern. A test van was borrowed from the FAATC MLS group which was driven in the vicinity of the localizer antenna as measurements were made at the test site. The van was approximately 20 feet long but was lower in height than the antenna elements. VFFM S/N 002 was connected to FFM antenna No. 1 and S/N 003 was fed from antenna No. 3. The PIR was alternatively fed from each of these antennas. The three existing MX 9026/GRN-27 monitors were each connected to a separate antenna. The Q-channel of each of the VFFM

TABLE 5-3. MONITOR RESPONSE TO FAATC R/W 13 TX. NO. 1 ADJUSTMENTS

Event	Existing Monitors		PIR	VFFM S/N 002			VFFM S/N 003			Remarks
	Mon. 1	Mon. 3	Ant. 1	Ant. 1			Ant. 3			
	Ant. 1	Ant. 1		I	Q	I&Q	I	Q	I&Q	
CSB Only	+2.25	+7.5	+.009	+6	+24	+25	+8	+11	+15	
+CAT I Alarm	+5	+3.5	+.014	+13	+25	+29	+13	+12	+18	
-CAT I Alarm	-3	-2.4	-.0045	-9	+25	+27	-6	+11	-14	
Normal	+1	-5	+.0045	+4	+24	+25	+4	+11	+12	
+CAT I Alarm	+5.75	+3.5	+.0165	+15	+23	+27	+15	+10	+19	No Q-Compensation
+2XCAT I Alarm	+10.5	+6.5	+.027	+24	+23	+34	+24	+11	+28	+ = 150 Hz
Normal	+1	+.025	-.0055	+4	+23	+24	+4	+11	+12	- = 90 Hz
-CAT I Alarm	-3	-2.25	-.0045	-9	+24	+25	-7	+11	-14	TX. No. 1
-2XCAT I Alarm	-8	-5.75	-.106	-18	+24	+31	-17	+11	-21	
Normal	-	-	-	+4	+2	+4.5	+3	+1	+3.5	
-CAT I Alarm	-3.5	-2.25	-.006	-9	+2	-10	-9	+1	-9	Full Q-Compensation
+CAT I Alarm	+6.5	+3.5	+.0175	+16	+2	+16.5	+14	+1	+14	TX. No. 1
Normal	+1	+.25	+.25	+5	+3	+6.5	+3	+1	+3	

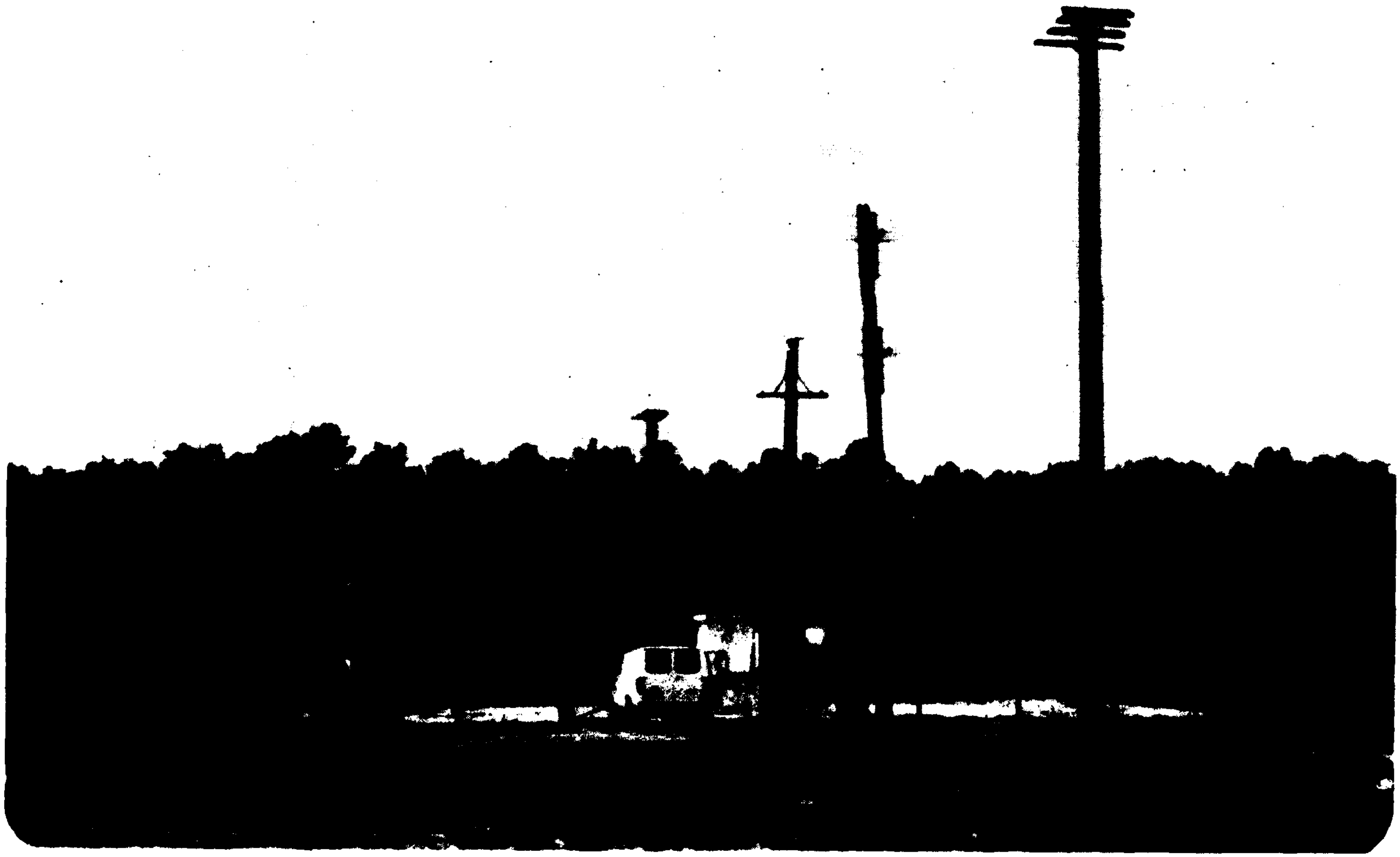


Figure 5-12. FAATC R/W 13 Test Site

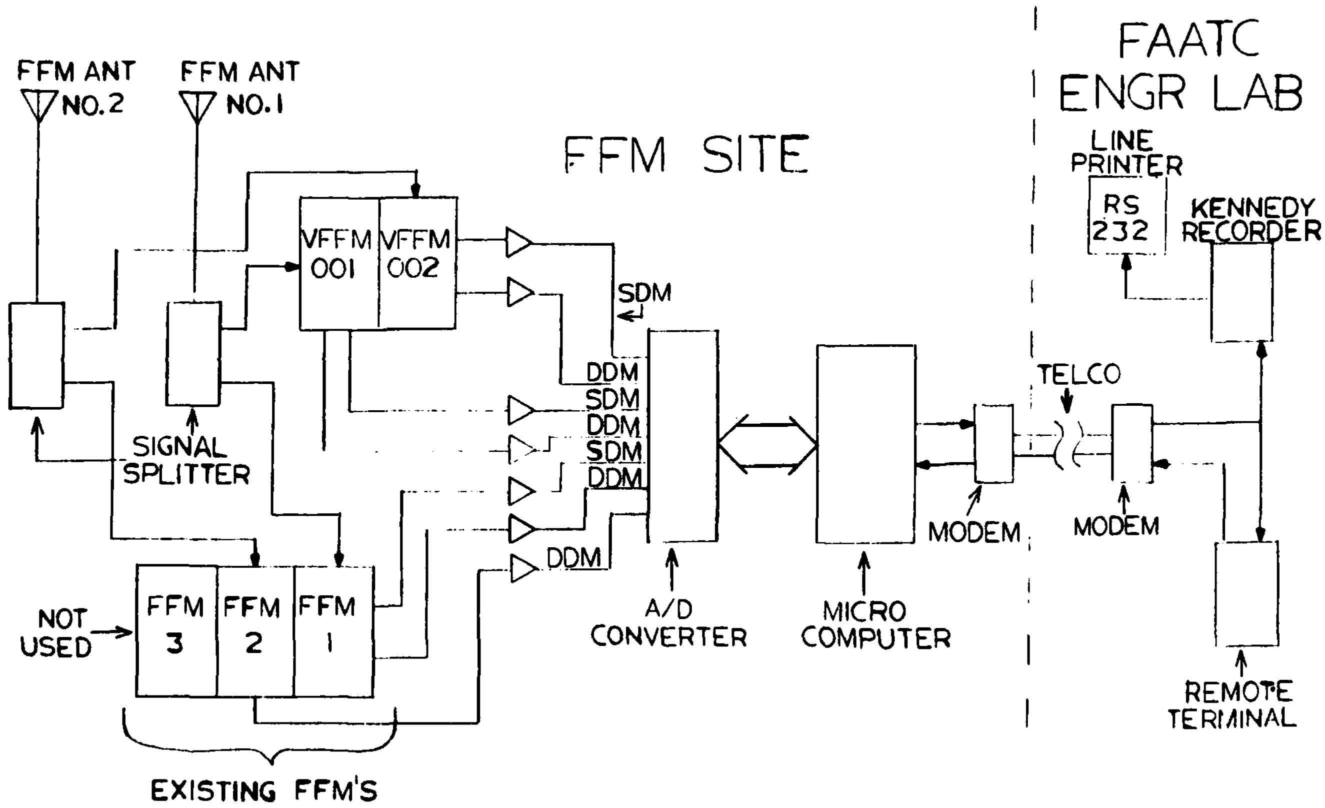


Figure 5-13. Block Diagram of RMS

TABLE 5-4. DDM VOLTAGE LEVELS FOR 150 HZ PREDOMINANT INPUTS

PMC Input 150 Hz	DDM OUTPUT FAA/FFM No. 2 Vdc	FAA/FFM No. 3 Vdc	VFFM No. 2 Vdc	VFFM No. 3 Vdc
0	-.026	-3.46	+.146	-3.56
.003	+.042	-3.39	+.27	-3.6
.005	+.090	-3.33	+.365	-3.58
.008	+.167	-3.23	+.492	-3.5
.010	+.202	-3.18	+.589	-3.42
.013	+.278	-3.14	+.71	-3.36
.015	+.318	-3.08	+.793	-3.28
.018	+.398	-3.01	+.92	-3.21
.020	+.453	-2.95	+1.03	-3.15
.023	+.513	-2.86	+1.163	-3.08
.025	+.574	-2.82	+1.241	-3.03
.028	+.636	-2.74	+1.363	-2.99
.030	+.690	-2.69	+1.45	-2.93
.040	+.908	-2.46	+1.85	-2.69
.050	+1.164	-2.20	-	-
.060	+1.4	-1.96	+2.73	-2.21
.070	+1.66	-1.70	-	-
.080	+1.9	-1.45	+3.62	-1.68
.090	+2.14	-1.2	-	-
.100	+2.38	-.93	+4.5	-1.15

TABLE 5-5. DDM VOLTAGE LEVELS FOR 90 HZ PREDOMINANT INPUTS

PMC Input 90 Hz	DDM OUTPUT FAA/FFM No. 2 Vdc	FAA/FFM No. 3 Vdc	VFFM No. 2 Vdc	VFFM No. 3 Vdc
0	-.023	-.134	-3.46	-3.57
.003	-.089	-.021	-3.48	-3.47
.005	-.135	-.071	-3.44	-3.42
.008	-.200	-.189	-3.40	-3.36
.010	-.244	-.283	-3.32	-3.31
.013	-.318	-.398	-3.27	-3.24
.015	-.369	-.496	-3.22	-3.21
.018	-.434	-.595	-3.14	-3.15
.020	-.485	-.694	-3.10	-3.12
.023	-.545	-.823	-3.06	-3.06
.025	-.600	-.930	-3.00	-3.01
.028	-.660	-1.04	-2.96	-2.98
.030	-.710	-1.14	-2.91	-2.92
.040	-.934	-1.56	-2.72	-2.70
.050	-1.19	-	-2.49	-
.060	-1.41	-2.43	-2.28	-2.28
.070	-1.63	-	-2.11	-
.080	-1.86	-	-1.90	-
.081	-	-3.36	-	-1.88
.090	-2.08	-	-1.66	-
.100	-2.30	-4.21	-1.48	-1.46

FAA/FFM				VFFM			
SDM NO.1	DDM NO.1	DDM NO.3	FLOATING	SDM NO.2	DDM NO.2	SDM NO.3	DDM NO.3
TIME:11:07:30							
-0.387	+0.133	+0.104	+4.996	+2.267	-3.563	+2.289	-3.422
TIME:11:07:31							
-0.385	+0.146	+0.104	+4.996	+2.267	-3.544	+2.279	-3.402
TIME:11:07:32							
-0.385	+0.148	+0.114	+4.996	+2.265	-3.551	+2.304	-3.405
TIME:11:07:33							
-0.382	+0.143	+0.092	+4.996	+2.267	-3.568	+2.299	-3.366
TIME:11:07:34							
-0.382	+0.158	+0.107	+4.996	+2.267	-3.558	+2.299	-3.390
TIME:11:07:35							
-0.392	+0.148	+0.109	+4.996	+2.252	-3.570	+2.291	-3.371
TIME:11:07:36							
-0.385	+0.151	+0.092	+4.996	+2.260	-3.558	+2.281	-3.373
TIME:11:07:37							
-0.392	+0.136	+0.094	+4.996	+2.265	-3.570	+2.311	-3.417
TIME:11:07:38							
-0.387	+0.151	+0.097	+4.996	+2.252	-3.556	+2.301	-3.395
TIME:11:07:39							
-0.387	+0.143	+0.092	+4.996	+2.262	-3.580	+2.289	-3.388
TIME:11:07:40							
-0.392	+0.143	+0.090	+4.996	+2.260	-3.570	+2.294	-3.417
TIME:11:07:41							
-0.382	+0.148	+0.099	+4.996	+2.265	-3.566	+2.284	-3.359
TIME:11:07:42							
-0.380	+0.141	+0.102	+4.996	+2.262	-3.570	+2.294	-3.336
TIME:11:07:43							
-0.380	+0.133	+0.092	+4.996	+2.257	-3.561	+2.299	-3.385
TIME:11:07:44							
-0.385	+0.156	+0.097	+4.996	+2.262	-3.549	+2.289	-3.378
TIME:11:07:45							
-0.382	+0.143	+0.099	+4.996	+2.272	-3.568	+2.289	-3.390
TIME:11:07:46							
-0.385	+0.138	+0.094	+4.996	+2.260	-3.554	+2.289	-3.361
TIME:11:07:47							
-0.385	+0.138	+0.094	+4.996	+2.272	-3.554	+2.296	-3.388
TIME:11:07:48							
-0.385	+0.153	+0.107	+4.996	+2.272	-3.561	+2.284	-3.356
TIME:11:07:49							
-0.382	+0.158	+0.097	+4.996	+2.272	-3.495	+2.281	-3.349
TIME:11:07:50							
-0.380	+0.151	+0.104	+4.996	+2.274	-3.568	+2.296	-3.354
TIME:11:07:51							
-0.387	+0.153	+0.099	+4.996	+2.265	-3.580	+2.284	-3.322
TIME:11:07:52							
-0.385	+0.131	+0.080	+4.996	+2.257	-3.556	+2.286	-3.388
TIME:11:07:53							
-0.390	+0.124	+0.094	+4.996	+2.260	-3.558	+2.286	-3.414

Figure 5.14. Sample Output of FAA's Digital Recording System

units was zeroed out to provide I_{PM} compensation. The data taken during this test is given in Table 5-6 and the relative location of the test van with respect to the localizer antenna is shown in Figure 5-15. In order to utilize the data taken and provide a baseline for plotting, it was necessary to normalize the data as shown in Table 5-7. The results of these tests indicate good correlation between in-phase DDM for all three types of receivers. Faults Nos. 8, 11, and 12 induced a relatively large Q output readings on the VFFM units which were not detected by the existing monitors or the PIR. As expected, the magnitude of the measured DDM (I and Q) was close to being the same as measured from either antenna No. 1 or No. 3. The VFFM I or Q channel readings should not necessarily correlate between the two antennas, the fact that they did must be attributed to the probability that the disturbance created by the parked test van was of a beam bend nature rather than a higher frequency interference. Figure 5-16 shows two of the VFFM units on the right and the MX-9026/GPN-27 FFM on the left. A plot of the normalized monitor response is shown in Figure 5-17 for the monitor units connected to the front (No. 1) antenna. Figure 5-18 is an identical plot for the rear (No. 3) antenna. The crosshatched areas represent points where the monitor alarm limits were exceeded. Note the large Q-signal for faults 8, 10, and 11.

5.4 LOCALIZER CSB MISPHASING CONDITION

Optimally, the localizer CSB signal (the carrier as modulated by the 90 Hz and 150 Hz tones) is adjusted for 0 DDM with the sidebands nominally of equal amplitude and in-phase. The VFFM being a phase sensitive receiver requires that the CSB signal be so adjusted that no CSB quadrature modulation components appear as a result of misphasing. The PIR and other ILS receivers are insensitive to CSB misphasing being only responsive to in-phase modulation of the carrier. The VFFM on the other hand detects both in- and out-of-phase signal components in order to accurately determine with a single antenna the scattering effects on the localizer signal created by multipath interference of the SBO signal. With the cooperation of BWI FAA personnel, the CSB outputs of the six localizer transmitters were sampled with a spectrum analyzer and the VFFM Q-channel. The six outputs displayed varying degrees of phase modulation components. The sideband levels as measured on the spectrum analyzer were unequal apparently in order to compensate for the misphasing. In order to overcome this problem, it was considered necessary to attempt to minimize the quadrature contribution to the CSB by inserting a phase shifter in the BWI R/W 10 localizer modulator assembly. The effect of the proposed adjustments on other system parameters, i.e., modulation, course alignment, and width would likely be minimal. In fact, it was believed that the effective radiated power necessary to achieve the useable distance requirement could be significantly reduced. The continuation of the VFFM test plan was doubtful unless the misphasing problem was overcome. It should be noted that none of the localizer transmitter misphasing conditions alluded to in this report are detrimental to system performance nor are they a reflection on the ability of the personnel assigned to maintain this equipment. The design of the phase sensitive VFFM equipment made it necessary to adopt such accurate transmitter alignment procedures in order to field test the equipment.

TABLE 5-6. FAATC R/W 13 EXTERNALLY INDUCED FAULT TESTS

Test Van	Existing FFMs			PIR (DDM)		VFFM (μA)					
Location	No. 1	No. 2	No. 3	Ant. 1	Ant. 3	S/N 002		Ant. 1	S/N 003		Ant. 3
	I	I	I	I	I	I	Q	I&Q	I	Q	I&Q
Normal	+1.5	+.5	+.10	+.0055	+.005	+5	2	+5	+5	2	+5
1	+2.5	+1.5	+2.0	+.009	+.002	+10	2	+11	+3	2	+3.5
2	+2.5	+1.5	+2.0	+.009	+.0075	+10	3	+10.5	+10	3	+10.5
3	-2.0	-1.5	-2.0	-.002	-.0025	-4.5	2	-5.5	-5.5	2	-6
4	-.5	-.5	-1.0	0	-.001	-3	2	-4	-3	2	-4
5	+2.5	+1.0	+2.0	+.0085	+.0065	+7	0	+7	+5.5	0	+5.5
6	+.5	0	0	+.003	+.002	+1	0	+1	0	0	0
7	0	0	-.5	+.0015	0	+1	0	+1	0	0	0
8	-1.0	-1.0	-1.5	0	-.00175	-3	14	-16.5	-3	16	-17
9	-3.5	-2.5	-3.5	-.00175	-.002	-1.5	3	-3.5	-4	2	-5.0
10	-2.0	-1.5	-2.0	-.0015	-.003	-1	0	-1	-2	0	-2
11	+2.0	+1.5	+2.0	+.0075	+.0075	+4	24	25	+4	24	+25
12	-2.0	-1.0	-1.5	-.002	-.002	-9	16	-19.5	-9	15	-1
13	+.25	0	0	+.0035	+.002	+3	2	+3.5	+2	2	+3
Normal	+1.5	+.5	+1.0	+.0055	+.0045	+5	2	+5	+4	2	+5

Notes: R/W 13 TX. No. 1

Q-channel compensation

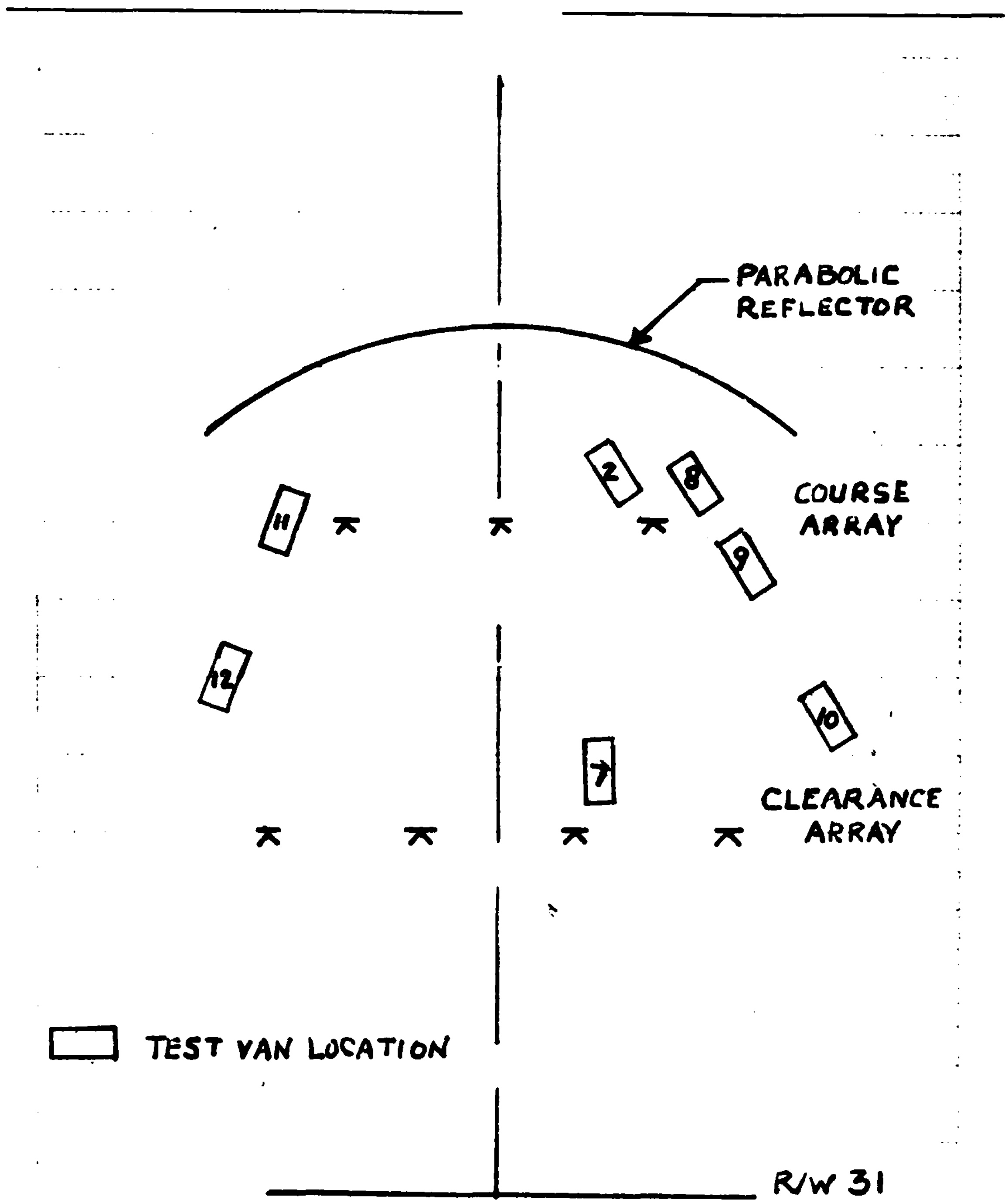


Figure 5-15. Relative Location of Test Van to the FAATC R/W 13 Localizer Antenna

TABLE 5-7. NORMALIZATION OF FAATC R/W 13 FAULT TEST DATA

Numerical Changes from Reference (Normal)

	FFM (F) (#1)	FFM (R) (#3)	PIR (F)	PIR (R)	VFFM (F) S/N 002			VFFM (R) S/N 003		
Absolute Normal	I +1.5	I +1.0	I +5.5	I +4.5	I +5	Q 2	I&Q 5	I +4	Q 2	I&Q 5
#2 (Fault)	+1	+1	3.5	3	5	1	5.5	6	1	5.5
3	-3.5	-3	-5.5	-7.0	-9.5	0	10.5	-9.5	0	-11
4	-2	-2	-5.5	-5.5	-8	0	-9	-7	0	-9
5	+1	+1	+3	+2	+2	-2	+2	+1.5	-2	+.5
6	-1	-1	-1.5	-2.5	-4	-2	-4	-4	-2	-5
7	-1.5	-1.5	-4.0	-4.5	-4	-2	-4	-4	-2	-5
8	-2.5	-2.5	-5.5	-6.0	-8	+12	-21.5	-7	+14	-22
9	-5.0	-4.5	-7	-6.5	-6.5	+1	-8.5	-8	0	-10
10	-3.5	-3	-7	-7.5	-6	-2	6	-6	-2	-3
11	+.5	+1	+2	+3	-1	+22	+20	0	+22	+20
12	-3.5	-2.5	-7.5	-6.5	-14	+14	-24.5	-13	+13	-24.5
13	+1.0	-1.0	-2	-2.5	-2	0	-1.5	-2	0	-2
Normal	0	0	0	0	0	0	0	0	0	0

CAT I	FFM (#1)	PIR	VFFM (#1,F)	VFFM (#3,R)
Alarm limits +	-4.5	-10.5	-11	-10
(from normal) -	+4.5	+11	+10	+11

F = Front antenna

R = Rear antenna

Figure 5-16. Test Equipment Setup in FAATC R/W 13 FFM Shelter

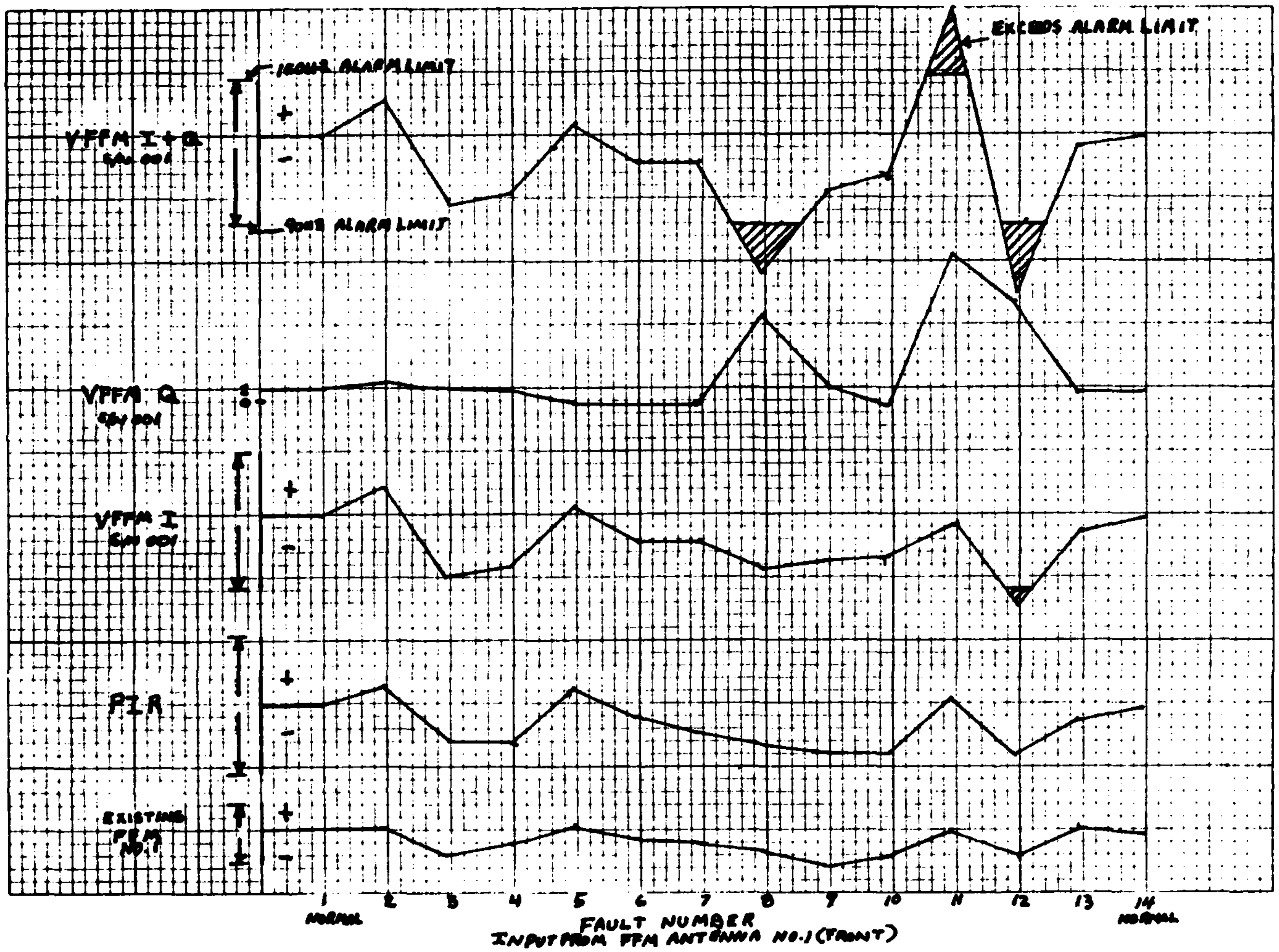


Figure 5-17. Monitor Response From Induced Fault Tests FAATC R/W 13 Antenna No. 1 (Front)

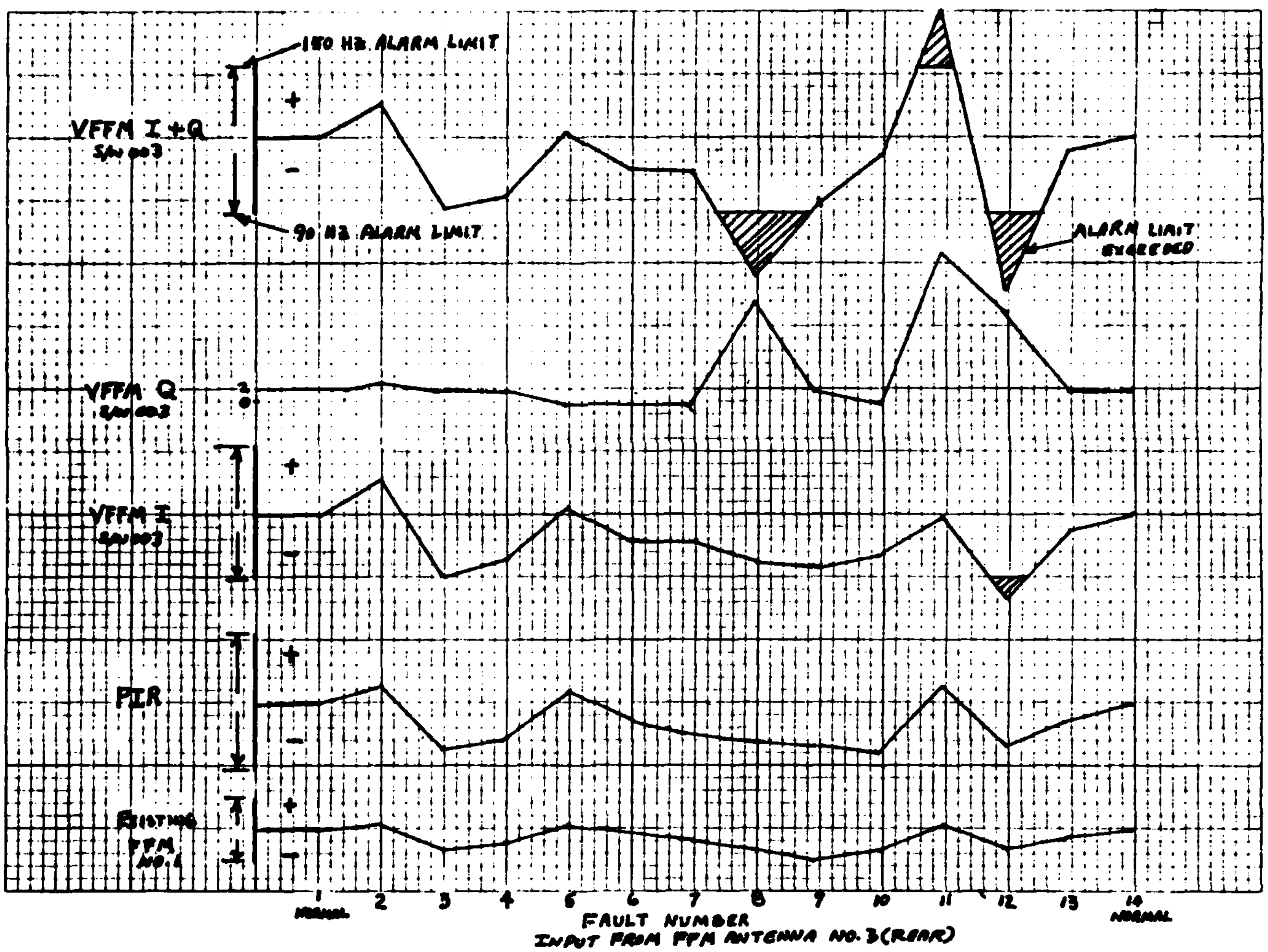


Figure 5-18. Monitor Response From Induced Fault Tests FAATC R/W 13
Antenna No. 3 (Rear)

5.4.1 TEST PLAN

The contract technical officer made a request for and obtained a test modification from the Airway Facilities Division Chief, AEA-400. It was not known at that time how much of the problem was a result of sideband to carrier misphasing or from sideband to sideband misphasing. Sideband to carrier phasing in the AN/GRN-27 localizer is controlled by an existing sideband phasor (A12A2). See Figure 5-19 for the schematic of the AN/GRN-27 modulator. If sufficient range were not available within this module, it was planned to insert an external phase shifter in series with cable W10. A sideband to sideband phasing adjustment is not built into the modulator equipment. It was planned to make this adjustment by installing an external phase shifter between the output of either the 90 Hz or 150 Hz sideband generator and the corresponding input to the sideband recombination bridge. The schematic diagram of the modulator assembly indicated than an SMB connector was available in each of these lines. Once the amount of phasing adjustment was determined, a cable length of equivalent phase length wuld be made and left in place.

5.4.2 PHASING ADJUSTMENT PROCEDURE

The condition experienced with the BWI localizers specifically the R/W 10 transmitter was simulated in the engineering lab in order to better understand the problem and to estimate the amount of phase adjustment which would be necessary in order to eliminate the quadrature component in the transmitter CSB output. This work took place while the request for equipment test modification was being processed, and was carried out using the ILS scattered signal simulator.

A. Bench Test of Sensitivity of Q-channel to Carrier Phase.

A measurement was made to determine how sensitive the quadrature component (Q-signal) of the VFFM output was to changes in RF carrier phase. This measurement was conducted in order to determine the amount of phase adjustment which would be required in the BWI R/W 10 localizer transmitter. The test circuit used to perform these measurements is shown in Figure 5-20 Phaser 1 was initially adjusted to eliminate the incidental PM inherent in the RF signal generator. Phaser 2 was adjusted to optimally align the SBO components from the hybrid junction such that when it was combined with the carrier there was no quadrature component present. The amount of phase difference introduced by phaser 2 was measured with a vector voltmeter. Measurements of Q-signal in microamps versus change in carrier phase were made at three different RF input power levels. The results are shown in Figure 5-21 which indicates that the sensitivity (slope) is approximately 7 microamps per degree of carrier phase, and that this sensitivity is essentially independent of RF level.

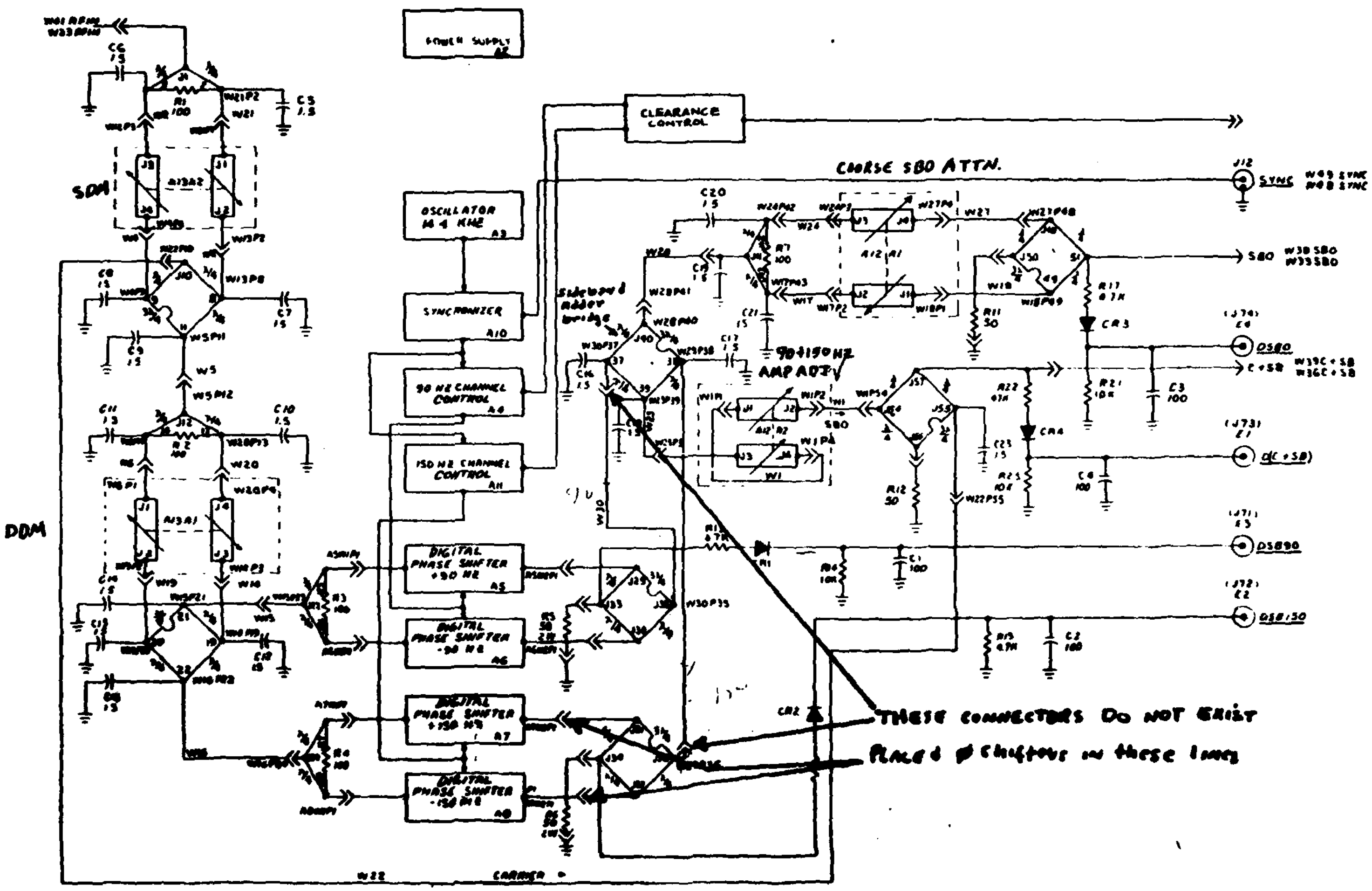


Figure 5-19. An/GRN-27 Localizer TX Modulator Schematic

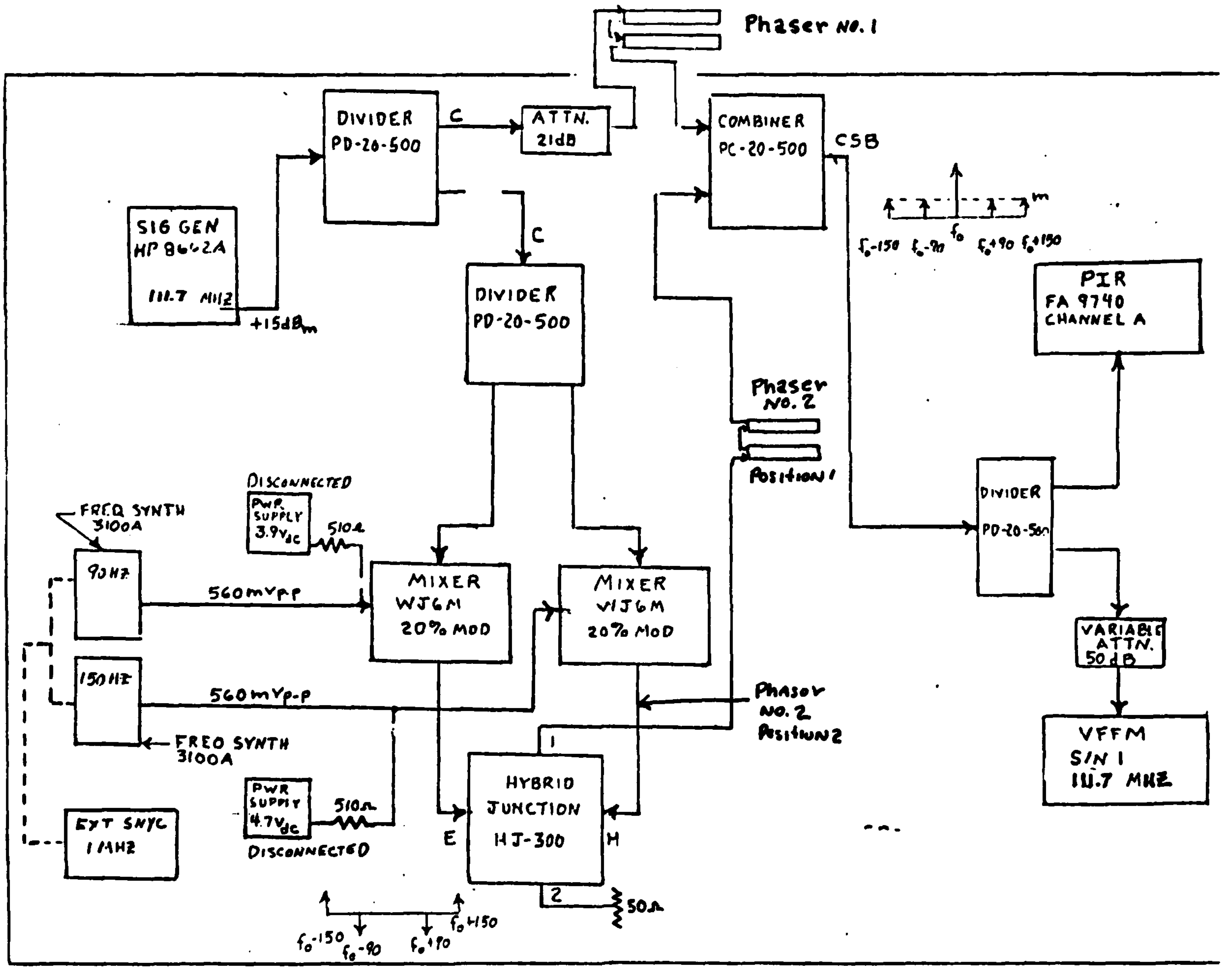


Figure 5-20. Test Setup for Measuring Sensitivity of Q-Signal to Carrier Phase

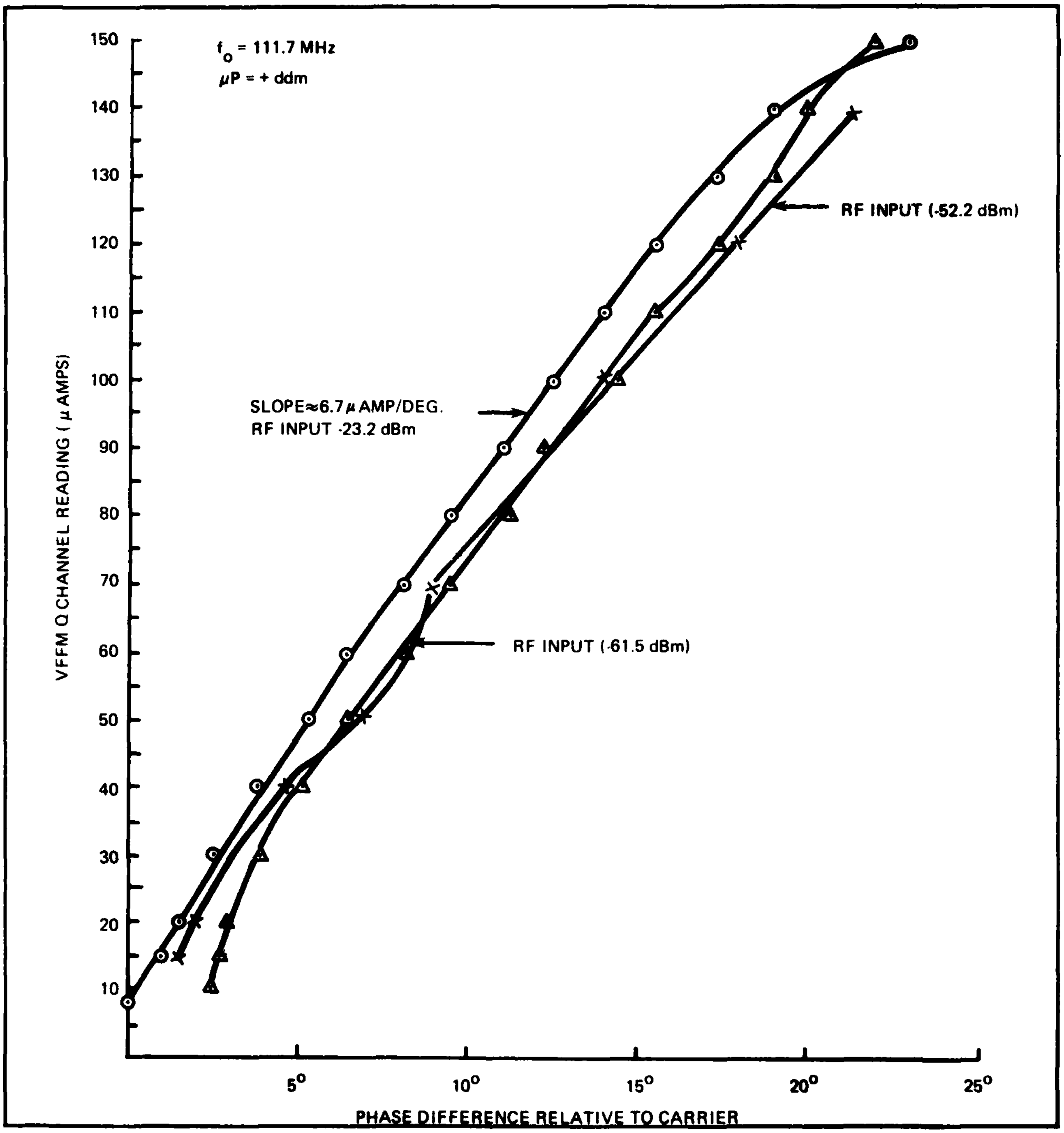


Figure 5-21. Plot of Q-Signal to Carrier Phase

B. Bench Test of Sensitivity of Q-signal to Sideband Phase.

In order to determine the magnitude of Q-signal which could be expected from sideband to sideband misphasing, phaser 2 was inserted between the output of the 150 Hz mixer and the H Port of the hybrid junction. All other parts of the circuit shown in Figure 5-20 remained the same. Both phasers were initially set to minimize Q-signal indication measured by the VFFM. The vector voltmeter was used to measure the phase of the 150 Hz sideband relative to the carrier. The results of this measurement is plotted in Figure 5-22. The Q-signal was found to be almost twice as sensitive as above, i.e., the slope was 12 microamps per degree phase. The conclusion of these measurements was that RF phasing in the localizer transmitter must be aligned much better than the 20 degree tolerance (Cat I and II) to minimize Q-signals if meaningful VFFM reflection measurements were to be made in the field.

C. Calculation of Cable Length.

In order to prepare for tuning the localizer transmitter at BWI R/W 10 special SMB connectors were obtained in order to interface the test phase shifters in the modulator assembly. The estimated amount of cable length required to minimize 80 microamps of Q-channel output was calculated:

f_0 = 109.70475 MHz
cable type = RG - 316
dielectric type = PTFE
$\epsilon = 1.5$

$$\lambda_{fs} = \frac{C}{fo} = \frac{29979.3}{(2.54)(109.70475}$$

$$\lambda_{fs} = 107.59 \text{ inches}$$

$$\lambda_{RG-316} = \frac{\lambda_{fs}}{\sqrt{\epsilon}} = \frac{107.59}{\sqrt{1.5}}$$

$$\lambda_{RG-316} = 87.85 \text{ inch}/360^{\circ}$$

$$\lambda_{RG-316} = 1 \text{ inch}/4.1^{\circ}$$

D. Phasing Adjustments at Test Site 'A'.

In order to ensure that the phase relationship between the course CSB and the course SBO signals was not responsible for the high VFFM Q-channel output, the VFFM receiver was connected to the existing FFM antenna and the rf phase shifter (1A29A2) was adjusted. This phasor was adjusted by as much as 13° with a corresponding reduction in Q-channel output of only 5 microamps. This test verified that although the VFFM was sensitive to rf phasing, the phase modulation component as measured at the far field test site was inherent in the CSB signal only.

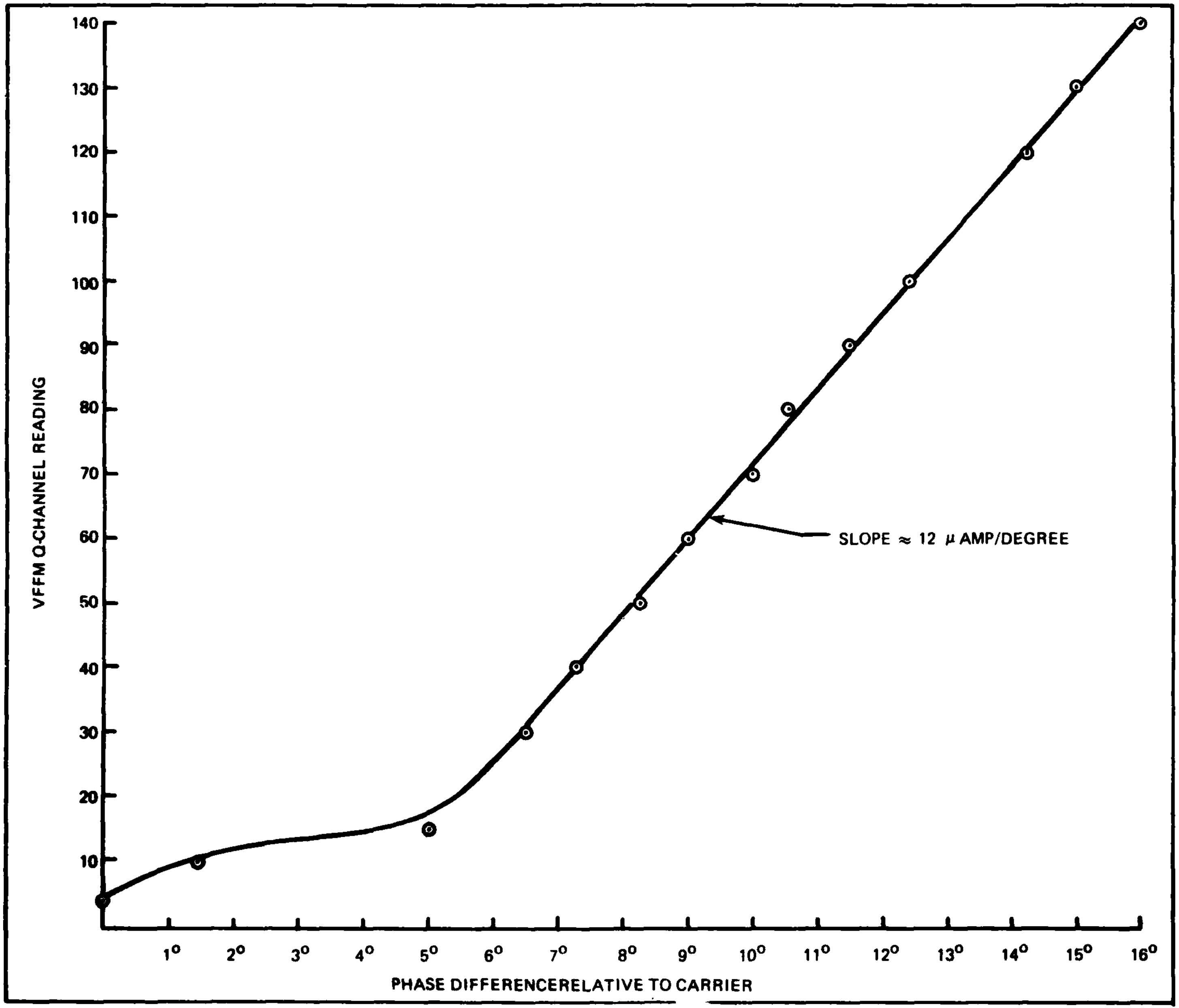


Figure 5-22. Plot of Q-Signal to Sideband Phase

E. Phasing Adjustments at the R/W 10 Localizer Transmitter Site.

Attempts were made to minimize the VFFM Q-channel output by making phasing adjustments within the R/W 10 Localizer transmitter modulator assembly. These adjustments were made only to TX. No. 2 since it displayed a much lower Q-signal ($\pm$30 microamps). Two types of phasing adjustments were made: (The results are shown in Table 5-8).

1. Adjustment of carrier to sideband phase. This was carried out by manually varying the existing carrier to sideband phase shifter (A12A2) which resulted in reducing the TX. No. 2 Q-output from 38 to 20 microamps.

2. Adjustment of the sideband to sideband phase. After the carrier to sideband phase was optimized, a 90^{o} phase shifter was installed in the output leg of each 90 Hz digital phase shifter. These phase shifters were adjusted for minimum Q-channel output as displayed on the VFFM. This resulted in a slight reduction of Q from 20 to 19.5 microamps; however, the in-phase channel increased from 1 to 3 microamps, (150 Hz predomminant). The pair of 90^{o} phase shifters were then removed from the 90 Hz digital phase shifters and inserted in the output of the 150 Hz units. A greater reduction in Q-output resulted (18 microamps min.); however, the I-channel increased to 4.2 microamps.

3. Adjustment of Sideband to Sideband Amplitude. After analyzing the results found in step 2, it was obvious that equalizing the sideband signal levels was necessary. Although nonphase shifting attenuators were available, a suitable insertion point could not be located in the modulator, even though connectors were shown to be available as shown on the schematic.

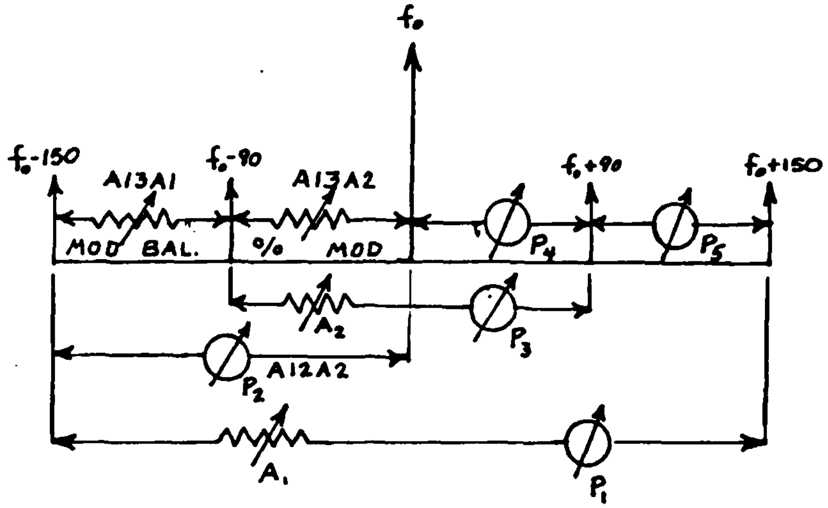
5.4.3 RESULTS OF LOCALIZER TRANSMITTER PHASING ADJUSTMENTS

The minimum Q-channel output achievable during the tuneup of TX No. 2 was 18 microamps. It was possible to equalize the amplitude level of either the upper or lower 90 Hz or 150 Hz sidebands by inserting external phase shifters; however, it was not mechanically possible to insert attenuators to equalize the 90 Hz sideband amplitudes with respect to the 150 Hz sidebands, since the inputs to the sideband recombination bridge are internal to the stripline boards. The procedure outlined on Figures 5-23 and 5-24 would have completely eliminated the incidental phase modulation of the CSB signal; however, the insertion of the indicated components would have required a major circuit modification to the AN/GRN-27 modulator assembly. Realizing that the resolution to this problem were better handled by providing Q-channel compensation within the VFFM equipment a contract modification was issued. The signal processor of the VFFM was extensively modified both in hardware and software form in order to compensate for localizer transmitter I_{PM} corresponding to as great as 60 microamps with no loss of receiver sensitivity or processor linearity. The resulting modification is fully described in Section 3. During the described transmitter adjustments

TABLE 5-8. BWI AIRPORT R/W 10 LOCALIZER PHASING ADJUSTMENTS

Location:	BWI R/W 10
System Type:	AN/GRN-27
Frequency:	109.70546 MHz
Transmitter:	No. 2
Date:	9/14/81

Condition	Sideband Levels Relative To Carrier				VFFM			PIR
	150_L	90_L	90_u	150_u	I	Q	I&Q	
Normal	-19.7	-19.7	-19.6	-19.5	1.5(150)	28.0	28+	.002(150)
Optimized A12A2	-	-	-	-	1.5(150)	20	21+	.002(150)
Phase Shifters in 90 Hz Lines	-19.8	-19.7	-19.7	-19.5	3(150)	19.5	20+	.0035(150)
Phase Shifters in 150 Hz Lines	-19.9	-19.7	-19.6	-19.6	4.25(150)	18	20+	.0045(150)



1. Remove 90 HZ channel control card. Adjust A1 for equal amplitude levels of 150 HZ tones.
2. Adjust P1 and P2 to remove quadrature components of the 150 HZ sidebands as measured on VFFM Q-channel.
3. Install 90 HZ channel control card and remove 150 HZ card. Adjust A2 for equal amplitude levels of 90 HZ tones.
4. Adjust P3 and P4 to remove quadrature components of the 90HZ sidebands as measured on the VFFM Q-channel.
5. Reinstall 150 HZ channel control card.
6. Adjust the modulation balance control A13A1 for minimum DDM as measured on PIR or VFFM I-channel.
7. Adjust the Percent Modulation Control A13A2 for 40% modulation as measured on the VFFM SDM Meter.

Note: Install either P4 or P5, both not required.

Location of components in AN/GRN-27 Modulator Assembly
A1 and P1 - In output of -150HZ Digital Phase shifter A8W2P1
A2 and P3 - In output of -90HZ Digital Phase shifter A6W2P1
P2 - Existing carrier to sideband phase shifter A12A2.
P4 - Output of DDM Power Divider.
P5 - At input 37 of sideband adder bridge.

Figure 5-23. Optimized Tuning Procedure for Eliminating I_{PM}

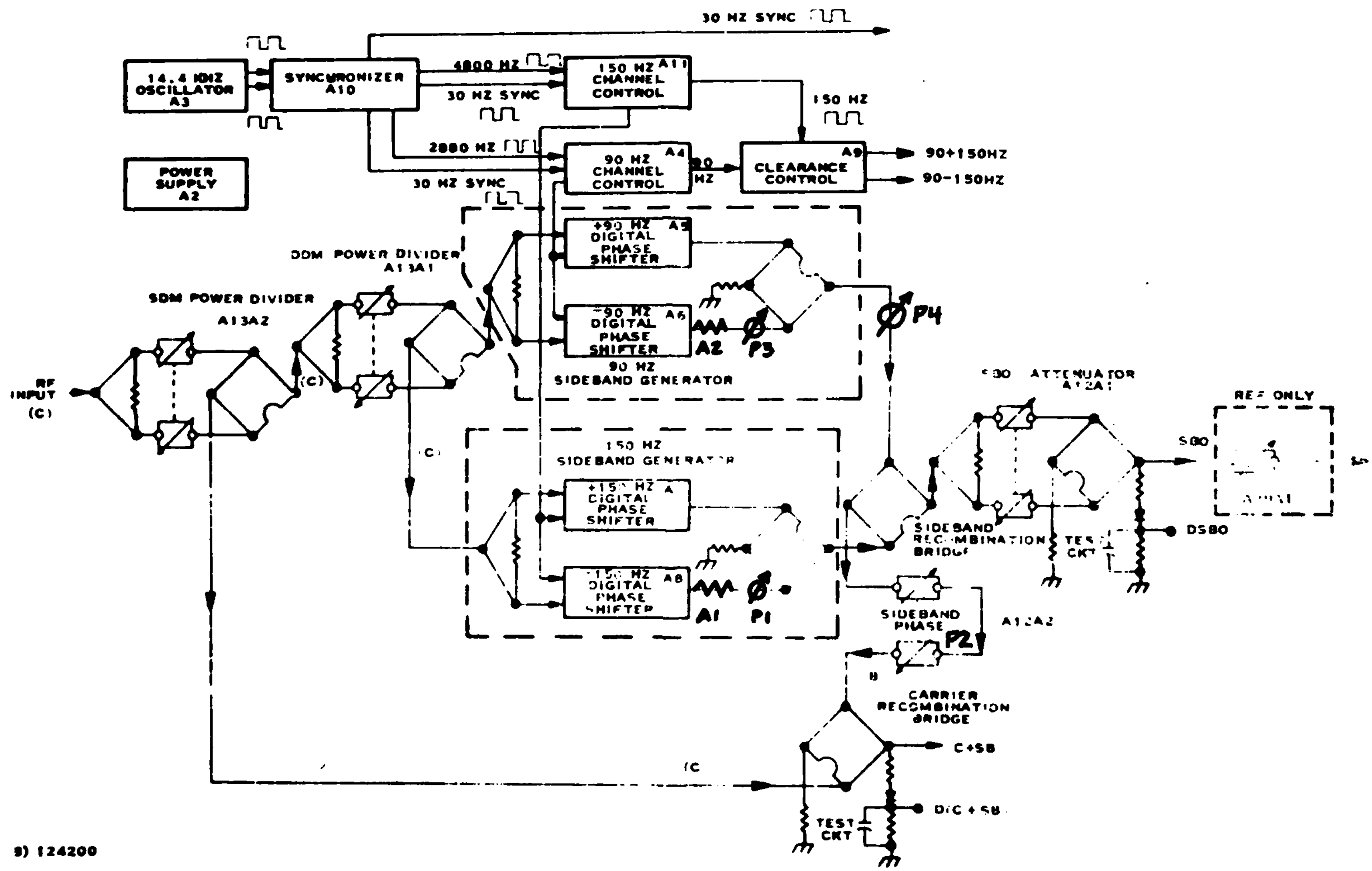


Figure 5-24. Location Points for External Phase Shifters and Attenuators in the AN/GRN-27 Modulator Assy

procedure, the usefulness of the VFFM as a precision piece of test equipment was illustrated. The unit can be used for localizer alignment procedures requiring phasing adjustments including:

(a) Sideband to carrier phasing adjustments in the CSB signal
(b) Modulator DDM phase shifter adjustments.
(c) Modulator SDM phase shifter adjustments.
(d) Course SBO to SCB phasing adjustments.

In effect, the VFFM performs the functions of the PIR but also is capable of determining SDM level and quadrature phase detection.

6.0 CONCLUSIONS AND RECOMMENDATIONS

This program has in effect followed through on some of the recommendations which were indicated in Report No. FAA-RD-79-70[1] under contract DOT-FA75WA-3689. A prototype version of a phase sensitive receiver and microprocessor was developed and field tests were conducted in an actual airport environment, under a variety of derogation conditions. This experimental program served to evaluate the feasibility of an executive localizer far field monitor and to determine the optimum monitor system configuration. The most significant findings which were determined include:

(a) The peak of the interference pattern on the localizer course can be determined from a measurement of the interference pattern envelope by using a single point measurement technique.

(b) Artificially induced radiation pattern disturbances conducted at the FAATC resulted in sizeable quadrature channel disturbances as measured by the VFFM system but which were undetected by the existing FFM system.

(c) The nature of the Vector Far Field Monitor DDM output can be used to discriminate between overflight and slow ground traffic disturbances; however, it was not possible to successfully filter out all interference caused by overflying aircraft.

(d) The VFFM equipment, in its prototype form, has the potential for use as a piece of test equipment for aligning the localizer transmitter to provide optimum sideband-to-sideband and carrier-to-sideband phasing. The test equipment presently used by the sectors makes this alignment difficult.

(e) Incidental phase modulation (I_{PM}) is probably inherent in all localizer transmitters but can be effectively compensated for in the VFFM equipment.

(f) Although it does not appear feasible to entirely eliminate a monitor alarm time delay, it can be substantially reduced.

Based on the results of these findings, certain recommendations are in order:

(a) Additional field testing is recommended under a controlled type of experiment in which target aircraft can be strategically maneuvered within the localizer critical area.

(b) In order to correlate the VFFM response to localizer course disturbances on the glide path, a validating flight check of the localizer course structure should be performed. This test will also serve to confirm that there is a definite relationship between the monitor response as measured at ground level and actual disturbance along the glide path.

(c) Through close liaison with FAA Air Traffic Control develop a strategy for the display of VFFM data.

7.0 ACKNOWLEDGEMENTS

Local FAA personnel at the test sites have extended every measure of cooperation to Westinghouse Electric Corporation engineers involved in this project. This working relationship has resulted in timely and affordable engineering results. Those people primarily responsible for this assistance include:

BWI Airport - Airway Facilities Sector AFS 812

Mr. A. Aquilano	Sector Chief
Mr. H. Hanson	Assistant Sector Chief
Mr. A. Scisione	Navaids Supervisor
Mr. J. Vinck	
Mr. D. Anders	Technicians
Mr. W. Williams	

Atlantic City Airport - AFSFO 823.6

Mr. R. Davis	Chief
Mr. G. Davidson	Assistant Chief
Mr. A. Most	Technician

FAATC - RMMS Group ACT-100L

Mr. R. Reyers	Group Leader
Mr. G. Horton	Engineer

8.0 REFERENCES

1. Westinghouse Electric Corporation, Aerospace and Electronic Systems Division, "Far Field Monitor for Instrument Landing Systems," Contract DOT-FA75WA-3689, Final Report, November 1979.

2. GEC - Marconi Electronics Limited, Response to proposal, No. WA5R-4-0508, June 1974.

3. Marschall, F. W., "Localizer far field monitor efforts, conclusions and suggestions," ANA-310 FAA-NAFEC, March 1973.

4. Horton, G. J., "A Low-Drift ILS Monitor," ACT-100L FAA-FAATC, May 1982.

5. Westinghouse Electric Corporation, Command and Control Division, "Proposal for a Vector Far Field Monitor," RFP No. DTFA01-80-R-15302, August 1980.

APPENDIX A

ASSEMBLY LANGUAGE PROGRAM FOR MICROPROCESSORS

```
ISIS-II 2920 ASSEMBLER V1.0                                          PAGE   1

ASSEMBLER INVOKED BY  AS2920  :F1:VFFM1.SRC

VECTOR FAR FIELD MONITOR -- 2920 #1     APR 1, 1982

  LINE   LOC OBJECT SOURCE STATEMENT

                       $      TITLE ('VECTOR FAR FIELD MONITOR -- 2920 #1     APR 1, 1982')
                       $      DEBUG
                       $      PAGELENGTH(58)
                       ;*****************************************************************
                       ;
                       ;       INTEL 2920 ASSEMBLY LANGUAGE PROGRAM FOR CALCULATING
                       ;       SDM(SUM OF DEPTHS OF MODULATION) AND DDM(DIFFERENCE IN
                       ;       DEPTHS OF MODULATION) FROM IN-PHASE AND QUADRATURE
                       ;       COMPONENTS FROM AN ILS LANDING SYSTEM TRANSMITER
                       ;
                       ;       THIS PROGRAM RESIDES IN 2920 #1 AND PERFORMS
                       ;       THE FIRST PART OF THE PROCESSING.
                       ;          -INPUTS 'IN-PHASE' (IN0) AND 'QUADRATURE' (IN1)
                       ;             SIGNALS.
                       ;          -FILTERS AND DETECTS THEM.
                       ;          -OUTPUTS SDM (OUT0),
                       ;          -OUTPUTS SIGN OF DDM (OUT2),
                       ;          -AND OUTPUTS SUM (OUT1) AND DIFFERENCE (OUT3) DATA
                       ;       (AN EXTERNAL OFFSET (IN2) IS ADDED TO 'SUM' BEFORE IT IS OUTPUT.)
                       ;
                       ;       THE SQUARE ROOT OF THE SUM OF THE SQUARES OF 'SUM' AND 'DIF'
                       ;       IS PERFORMED IN SECOND 2920 CHIP (2920 #2)
                       ;
                       ;       USE IS IN THE VECTOR FAR FIELD MONITOR FOR THE FAA.
                       ;
                       ;
                       ;*****************************************************************
                       ;
                       ;
                       OUT2_P2 EQU OUT2_P1
                       OUT2_P3 EQU OUT2_P1
                       OUT2_P4 EQU OUT2_P1
                       OUT2_P5 EQU OUT2_P1
                       OUT2_P6 EQU OUT2_P1
                       OUT2_P7 EQU OUT2_P1
                       OUT2_P8 EQU OUT2_P1
                       OUT1_P9 EQU OUT2_P1
                       OUT1_P10 EQU OUT2_P1
                       OUT1_P11 EQU OUT2_P1
                       OUT1_P12 EQU OUT2_P1
                       ;*****************************************************************
                       ;
                       ;
                       ;        DEFINITION OF ALL VARIABLE NAMES USED
```

```
ISIS-II 2920 ASSEMBLER V1.0                                      PAGE   2

VECTOR FAR FIELD MONITOR -- 2920 #1     APR 1, 1982

  LINE  LOC OBJECT SOURCE STATEMENT

                     ;
                     ;          PHSIG          IN-PHASE CHANNEL INPUT
                     ;          OUT0_PX        OUTPUT OF FILTER FROM POLE # X
                     ;          OUT1_PX        OUTPUT OF FILTER FROM POLE # X, DELAYED
                     ;                         BY 1 SAMPLE INTERVAL
                     ;          OUT2_PX        OUTPUT OF FILTER FROM POLE # X, DELAYED
                     ;                         BY 2 SAMPLE INTERVALS
                     ;          IN90           IN-PHASE INPUT FILTERED BY 90 HZ BPF
                     ;          IN150          IN-PHASE INPUT FILTERED BY 150 HZ BPF
                     ;          QD90           QUADRATURE INPUT FILTERED BY 90 HZ BPF
                     ;          QD150          QUADRATURE INPUT FILTERED BY 150 HZ BPF
                     ;          NEW90          ABSOLUTE VALUE OF IN90 OR QD90
                     ;          NEW150         ABSOLUTE VALUE OF IN150 OR QD150
                     ;          PKIN90         OUTPUT OF PEAK DETECTOR FOR IN90
                     ;          PKIN150        OUTPUT OF PEAK DETECTOR FOR IN150
                     ;          PKQD90         OUTPUT OF PEAK DETECTOR FOR QD90
                     ;          PKQD150        OUTPUT OF PEAK DETECTOR FOR QD150
                     ;          ENVIN90        OUTPUT OF ENVELOPE DETECTOR FOR IN90
                     ;          ENVIN150       OUTPUT OF ENVELOPE DETECTOR FOR IN150
                     ;          ENVQD90        OUTPUT OF ENVELOPE DETECTOR FOR QD90
                     ;          ENVQD150       OUTPUT OF ENVELOPE DETECTOR FOR QD150
                     ;          COUNT          COUNT FROM 64 TO 0 FOR ENVELOPE DETECTOR
                     ;          CMP            ENVIN150 - ENVIN90 (IN-PHASE DIFFERENCE)
                     ;          QOFF           EXTERNAL OFFSET ADDED TO QUADRATURE SUM
                     ;
                     ;                INPUT AND OUTPUT ASSIGNMENTS ON 2920 #1
                     ;
                     ;          IN0            IN-PHASE CHANNEL INPUT
                     ;          IN1            QUADRATURE CHANNEL INPUT
                     ;          IN2            EXTERNAL OFFSET TO QUAD SUM
                     ;          OUT0           SDM OUTPUT
                     ;          OUT1           SUM OF 150HZ AND 90HZ FILTERS FROM QUADRATURE INPUT
                     ;          OUT2           DDM SIGN OUTPUT
                     ;          OUT3           DIFFERENCE BETWEEN 150HZ AND 90HZ FILTERS
                     ;                          FROM IN-PHASE INPUT.
                     ;
                     ;***********************************************************
                     ;
                     ;   INPUT OFFSET TO BE ADDED TO QUADRATURE SUM.
                     ;
       0 40083C ADD CMP, CMP, R02              ;FINAL GAIN ADJUSTMENT
       1 40087C ADD CMP, CMP, R04
       2 404C7F LDA DAR, CMP, R00              ;OUTPUT DIFFERENCE SIGNAL
       3 40CE   ADD DAR, KP1, R01
       4 4000EF NOP
       5 4000EF NOP
```

```
ISIS-II 2920 ASSEMBLER V1 0                                        PAGE   3
VECTOR FAR FIELD MONITOR -- 2920 #1     APR 1, 1982
  LINE  LOC OBJECT SOURCE STATEMENT

    91    6 4000EF NOP
    92    7 B000EF OUT3
    93    8 B000EF OUT3
    94    9 B000EF OUT3
    95   10 B000EF OUT3
    96   11 4000EF NOP
    97   12 4000EF NOP
    98   13 4000EF NOP
    99   14 2066EB SUB DAR , DAR,   R0,  IN2       ;GET READY TO A/D OFFSET
   100   15 2000EF IN2
   101   16 2000EF IN2
   102   17 2000EF IN2
   103   18 2000EF IN2
   104   19 4000EF NOP
   105   20 4000EF NOP
   106   21 6000EF CVTS
   107   22 EBE6ED ADD DAR , KM2,   R00,  CND6
   108   23 4000EF NOP
   109   24 4000EF NOP
   110   25 7100EF CVT7
   111   26 4000EF NOP
   112   27 4000EF NOP
   113   28 6100EF CVT6
   114   29 4000EF NOP
   115   30 4000EF NOP
   116   31 5100EF CVT5
   117   32 4000EF NOP
   118   33 4000EF NOP
   119   34 4100EF CVT4
   120   35 4000EF NOP
   121   36 4000EF NOP
   122   37 3100EF CVT3
   123   38 4000EF NOP
   124   39 4000EF NOP
   125   40 2100EF CVT2
   126   41 4000EF NOP
   127   42 4000EF NOP
   128   43 1100EF CVT1
   129   44 4000EF NOP
   130   45 4000EF NOP
   131   46 0100EF CVT0
   132   47 4422EF LDA GOFF, DAR                    ;SAVE CONVERTED OFFSET
   133              ;*************************************************************
   134              ;
   135              ;    START OF 90HZ BPF
   136              ;
```

```
ISIS-II 2920 ASSEMBLER V1.0                                        PAGE    4
VECTOR FAR FIELD MONITOR -- 2920 #1     APR 1, 1982
 LINE  LOC OBJECT SOURCE STATEMENT
                  ;     FILTER CONTAINS ONE ZERO AT 0.0 AND TWO POLE PAIRS, BOTH
                  ;     BEING AT -10.2,90.
                  ;
                  ;     FILTER Q = 9 AND GROUP DELAY OVER 2 HZ = 1.2 MSEC
                  ;
                  ;*****************************************************************
                  ;
                  ;CODE FOR POLE PAIR 1 FOR 90HZ BPF
                  ;
      48 4208EF LDA OUT2_P1,OUT1_P1,R00
      49 404CE5 LIM DAR , CMF                          ;OUTPUT SIGN OF DDM
      50 4C00FF LDA OUT1_P1,OUT0_P1,R00
      51 48182E LDA OUT0_P1,PHSIG,R02
      52 4010EB SUB OUT0_P1,OUT2_P1,R00
      53 A218CD ADD OUT0_P1,OUT1_P1,L01,OUT2
      54 A2188A SUB OUT0_P1,OUT1_P1,R05,OUT2
      55 A010AC ADD OUT0_P1,OUT2_P1,R06,OUT2
      56 4010EC ADD OUT0_P1,OUT2_P1,R08
      57 4218EC ADD OUT0_P1,OUT1_P1,R08
      58 42186D ADD OUT0_P1,OUT1_P1,R12
                       ;OUT0_P1=1.9729003*OUT1_P1-0.98046875*OUT2_P1+1*IN0_P1
                  ;
                  ;CODE FOR POLE PAIR 2 FOR 90HZ BPF
                  ;
      59 4A00EF LDA OUT2_P2,OUT1_P2,R00
                      ; OUT2_P2=1.00000000*OUT1_P2
      60 1066EB SUB DAR,DAR,R00,IN1
      61 1E18EF LDA OUT1_P2,OUT0_P2,R00,IN1
                      ; OUT1_P2=1.00000000*OUT0_P2
      62 1C101F LDA OUT0_P2,OUT0_P1,R09,IN1
      63 1410FB SUB OUT0_P2,OUT2_P2,R00,IN1
      64 1E10DD ADD OUT0_P2,OUT1_P2,L01,IN1
      65 1E109A SUB OUT0_P2,OUT1_P2,R05,IN1
      66 4410BC ADD OUT0_P2,OUT2_P2,R06
      67 4410FC ADD OUT0_P2,OUT2_P2,R08
      68 6E10FC ADD OUT0_P2,OUT1_P2,R08,CVTS
      69 EBE6ED ADD DAR,KM2,R00,CND6
      70 4E107D ADD OUT0_P2,OUT1_P2,R12
                      ; OUT0_P2=1.9729003*OUT1_P2-0.98046875*OUT2_P2+1*IN0_P2
                  ;
                  ;CODE FOR ZERO 1 FOR 90HZ BPF
                  ;
      71 4A48EF LDA IN90,OUT0_P2,R00
                      ; OUT0_Z1=1.00000000*IN0_Z1
      72 7B40EB SUB IN90,OUT1_P2,R00,CVT7
                      ; OUT0_Z1=-1.00000000*IN1_Z1+1.00000000*IN0_Z1
```

```
ISIS-II 2920 ASSEMBLER V1.0                                        PAGE    5
VECTOR FAR FIELD MONITOR -- 2920 #1     APR 1, 1982
  LINE  LOC OBJECT SOURCE STATEMENT
                   ;END OF 90HZ BPF
                   ;
        73 4060B7 ABS NEW90,IN90,L02      ;NEW90=(\90 HZ FILTERED IN PHASE\)/4
                   ;*************************************************************
                   ;
                   ;START OF 150HZ BPF
                   ;
                   ;   FILTER CONTAINS ONE ZERO AT 0,0 AND TWO POLE PAIRS,BOTH
                   ;   BEING AT -9.4,150.7.
                   ;
                   ;   FILTER Q = 16 AND GROUP DELAY OVER 2 HZ = 1.7 MSEC.
                   ;
                   ;*************************************************************
                   ;
                   ;CODE FOR POLE PAIR 1 OF 150HZ BPF
                   ;
        74 4220EF LDA OUT2_P3,OUT1_P3,R00
                   ;  OUT2_P3=1.00000000*OUT1_P3
        75 6768EF LDA OUT1_P3,OUT0_P3,R00,CVT6
                   ;  OUT1_P3=1.00000000*OUT0_P3
        76 4440BE LDA OUT0_P3,OUT2_P3,R06
                   ;  OUT0_P3=0.0156250000*OUT2_P3
        77 44401D ADD OUT0_P3,OUT2_P3,R09
                   ;  OUT0_P3=0.017578125*OUT2_P3
        78 55405D ADD OUT0_P3,OUT2_P3,R11,CVT5
                   ;  OUT0_P3=0.018066406*OUT2_P3
        79 4440FB SUB OUT0_P3,OUT2_P3,R00
                   ;  OUT0_P3=-0.98193359*OUT2_P3
        80 46609A SUB OUT0_P3,OUT1_P3,R05
                   ;  OUT0_P3=-0.031250000*OUT1_P3-0.98193359*OUT2_P3
        81 4760DA SUB OUT0_P3,OUT1_P3,R07,CVT4
                   ;  OUT0_P3=-0.039062500*OUT1_P3-0.98193359*OUT2_P3
        82 4660DD ADD OUT0_P3,OUT1_P3,L01
                   ;  OUT0_P3=1.9609375*OUT1_P3-0.98193359*OUT2_P3
        83 4C481C ADD OUT0_P3,PHSIG,R01
                   ;  OUT0_P3=1.9609375*OUT1_P3-0.98193359*OUT2_P3+1*IN0_P3
                   ;
                   ;CODE FOR POLE PAIR 2 FOR 150HZ BPF
                   ;
        84 3920EF LDA OUT2_P4,OUT1_P4,R00,CVT3
                   ;  OUT2_P4=1.00000000*OUT1_P4
        85 4878EF LDA OUT1_P4,OUT0_P4,R00
                   ;  OUT1_P4=1.00000000*OUT0_P4
        86 4050BE LDA OUT0_P4,OUT2_P4,R06
                   ;  OUT0_P4=0.0156250000*OUT2_P4
        87 21501D ADD OUT0_P4,OUT2_P4,R09,CVT2
```

```
ISIS-II 2920 ASSEMBLER V1.0                                        PAGE    6
VECTOR FAR FIELD MONITOR -- 2920 #1     APR 1, 1982
  LINE  LOC OBJECT SOURCE STATEMENT
                   ; OUTO_P4=0.017578125*OUT2_P4
        88 40505D ADD OUTO_P4,OUT2_P4,R11
                   ; OUTO_P4=0.018066406*OUT2_P4
        89 4050FB SUB OUTO_P4,OUT2_P4,R00
                   ; OUTO_P4=-0.98193359*OUT2_P4
        90 19709A SUB OUTO_P4,OUT1_P4,R05,CVT1
                   ; OUTO_P4=-0.031250000*OUT1_P4-0.98193359*OUT2_P4
        91 4870DA SUB OUTO_P4,OUT1_P4,R07
                   ; OUTO_P4=-0.039062500*OUT1_P4-0.98193359*OUT2_P4
        92 4870DD ADD OUTO_P4,OUT1_P4,L01
                   ; OUTO_P4=1.9609375*OUT1_P4-0.98193359*OUT2_P4
        93 03781D ADD OUTO_P4,OUTO_P3,R09,CVTO
                   ; OUTO_P4=1.9609375*OUT1_P4-0.98193359*OUT2_P4+1*INO_P4
                  ;
                  ;CODE FOR ZERO 1 FOR 150HZ BPF
                  ;
        94 4C78EF LDA IN150,OUTO_P4,R00
                   ; OUTO_Z2=1.00000000*INO_Z2
        95 4C70EB SUB IN150,OUT1_P4,R00
                   ; OUTO_Z2=-1.00000000*IN1_Z2+1.00000000*INO_Z2
                  ;END OF 150HZ BPF
                  ;
        96 4472FE LDA QDSIG,DAR,R08    ;QDSIG = QUADRATURE INPUT
        97 4A21A7 ABS NEW150,IN150,L02
                  ;***********************************************************
                  ;
                  ;START OF 90 HZ IN PHASE PEAK DETECTOR
                  ;
        98 40CCEF LDA DAR,PKIN90,R00       ;DAR = OLD PEAK
        99 406CAB SUB DAR,NEW90,L02        ;DAR = OLD - NEW
       100 70298F LDA PKIN90,NEW90,L02,CNDS ;PKIN90=NEW90 IF NEW90>PKIN90
                  ;END OF 90 HZ IN PHASE PEAK DETECTOR;
                  ;***********************************************************
       101 40816A SUB NEW150,NEW150,R04
       102 40812A SUB NEW150,NEW150,R02 ;NEW150=\150 HZ FILTERED IN PHASE\/4
                  ;***********************************************************
                  ;
                  ;START OF 150 HZ IN PHASE PEAK DETECTOR
                  ;
       103 42C4EF LDA DAR,PKIN150,R00      ;DAR = OLD PEAK
       104 40C4AB SUB DAR,NEW150,L02       ;DAR = OLD - NEW
       105 4288FF LDA CMP,ENVIN150
       106 7481AF LDA PKIN150,NEW150,L02,CNDS;PKIN150=NEW150 IF NEW150>PKIN150
                  ;END OF 150 HZ IN PHASE PEAK DETECTOR
                  ;***********************************************************
       107 48C4EF LDA DAR,ENVIN90,R00
```

```
ISIS-II 2920 ASSEMBLER V1.0                                         PAGE    7
VECTOR FAR FIELD MONITOR -- 2920 #1     APR 1, 1982
  LINE  LOC OBJECT SOURCE STATEMENT
   275  108 42CCED ADD DAR,ENVIN150,R00          ;DAR = IN PHASE SUM
   276  109 4880FB SUB CMP,ENVIN90               ;CMP = \ENVIN150\ - \ENVIN90\
   277  110 4008FD ADD CMP,CMP
   278                 ;*************************************************************
   279                 ;
   280                 ;START OF 90HZ BPF
   281                 ;
   282                 ;     SAME AS PREVIOUS 90 HZ BPF
   283                 ;
   284                 ;*************************************************************
   285                 ;
   286                 ;CODE FOR POLE PAIR 1 FOR 90HZ BPF
   287                 ;
   288  111 4888EF LDA OUT2_P5,OUT1_P5,R00
   289                    ;  OUT2_P5=1.00000000*OUT1_P5
   290  112 4A91FF LDA OUT1_P5,OUT0_P5,R00
   291                    ;  OUT1_P5=1.00000000*OUT0_P5
   292  113 8E392E LDA OUT0_P5,QDSIG,R02,OUT0
   293  114 8411EB SUB OUT0_P5,OUT2_P5,R00,OUT0      ;OUT0 = ENVIN90/2 + ENVIN150/2 = SDM
   294  115 8C99CD ADD OUT0_P5,OUT1_P5,L01,OUT0
   295  116 4C998A SUB OUT0_P5,OUT1_P5,R05
   296  117 4411AC ADD OUT0_P5,OUT2_P5,R06
   297  118 0066EB SUB DAR,DAR,R00,INO
   298  119 0411EC ADD OUT0_P5,OUT2_P5,R08,INO
   299  120 0C99EC ADD OUT0_P5,OUT1_P5,R08,INO
   300  121 0C996D ADD OUT0_P5,OUT1_P5,R12,INO
   301                    ;  OUT0_P5=1.9729003*OUT1_P5-0.98046875*OUT2_P5+1*INO_P5
   302                 ;
   303                 ;CODE FOR POLE PAIR 2 FOR 90HZ BPF
   304                 ;
   305  122 0A88EF LDA OUT2_P6,OUT1_P6,R00,INO
   306                    ;  OUT2_P6=1.00000000*OUT1_P6
   307  123 04B1FF LDA OUT1_P6,OUT0_P6,R00,INO
   308                    ;  OUT1_P6=1.00000000*OUT0_P6
   309  124 4AC10F LDA OUT0_P6,OUT0_P5,R09
   310  125 4041EB SUB OUT0_P6,OUT2_P6,R00
   311  126 6AC9CD ADD OUT0_P6,OUT1_P6,L01,CVTS
   312  127 EBE6ED ADD DAR,KM2,R00,CND6
   313  128 4AC98A SUB OUT0_P6,OUT1_P6,R05
   314  129 4041AC ADD OUT0_P6,OUT2_P6,R06
   315  130 7141EC ADD OUT0_P6,OUT2_P6,R08,CVT7
   316  131 4AC9EC ADD OUT0_P6,OUT1_P6,R08
   317  132 4AC96D ADD OUT0_P6,OUT1_P6,R12
   318                    ;  OUT0_P6=1.9729003*OUT1_P6-0.98046875*OUT2_P6+1*INO_P6
   319                 ;
   320                 ;CODE FOR ZERO 1 FOR 90HZ BPF
```

```
ISIS-II 2920 ASSEMBLER V1.0                                   RAGE   8
VECTOR FAR FIELD MONITOR -- 2920 #1     APR 1, 1982
  LINE  LOC OBJECT SOURCE STATEMENT

                  ;
      133 61E1FF LDA GD90,OUTO_P6,R00,CVT6
                    ; OUTO_Z3=1.00000000*INO_Z3
      134 4AC9FB SUB GD90,OUT1_P6,R00
                    ; OUTO_Z3=-1.00000000*IN1_Z3+1.00000000*INO_Z3
                 ;END OF 90HZ BPF
                 ;
      135 40EBB7 ABS NEW90,GD90,L02
                                    ;NEW90 =(\90 HZ FILTERED QUADRATURE\)/4
                 ;************************************************************
                 ;
                 ;START OF 150HZ BPF
                 ;
                 ;     SAME AS PREVIOUS 150 HZ BPF
                 ;
                 ;************************************************************
                 ;
                 ;CODE FOR POLE PAIR 1 OF 150HZ BPF
                 ;
      136 53A0EF LDA OUT2_P7,OUT1_P7,R00,CVT5
                    ; OUT2_P7=1.00000000*OUT1_P7
      137 46E9EF LDA OUT1_P7,OUTO_P7,R00
                    ; OUT1_P7=1.00000000*OUTO_P7
      138 4441BE LDA OUTO_P7,OUT2_P7,R06
                    ; OUTO_P7=0.0156250000*OUT2_P7
      139 45411D ADD OUTO_P7,OUT2_P7,R09,CVT4
                    ; OUTO_P7=0.017578125*OUT2_P7
      140 44415D ADD OUTO_P7,OUT2_P7,R11
                    ; OUTO_P7=0.018066406*OUT2_P7
      141 4441FB SUB OUTO_P7,OUT2_P7,R00
                    ; OUTO_P7=-0.98193359*OUT2_P7
      142 37E19A SUB OUTO_P7,OUT1_P7,R05,CVT3
                    ; OUTO_P7=-0.031250000*OUT1_P7-0.98193359*OUT2_P7
      143 46E1DA SUB OUTO_P7,OUT1_P7,R07
                    ; OUTO_P7=-0.039062500*OUT1_P7-0.98193359*OUT2_P7
      144 46E1DD ADD OUTO_P7,OUT1_P7,L01
                    ; OUTO_P7=1.9609375*OUT1_P7-0.98193359*OUT2_P7
      145 2F691C ADD OUTO_P7,GDSIG,R01,CVT2
                    ; OUTO_P7=1.9609375*OUT1_P7-0.98193359*OUT2_P7+1*INO_P7
                 ;
                 ;CODE FOR POLE PAIR 2 FOR 150HZ BPF
                 ;
      146 48A0EF LDA OUT2_P8,OUT1_P8,R00
                    ; OUT2_P8=1.00000000*OUT1_P8
      147 48F9EF LDA OUT1_P8,OUTO_P8,R00
                    ; OUT1_P8=1.00000000*OUTO_P8
```

```
ISIS-II 2920 ASSEMBLER V1 0                                         PAGE    9
VECTOR FAR FIELD MONITOR -- 2920 #1     APR 1, 1982
  LINE  LOC OBJECT SOURCE STATEMENT
        148 1151BE LDA OUT0_P8,OUT2_P8,R06,CVT1
                      ; OUT0_P8=0.0156250000*OUT2_P8
        149 40511D ADD OUT0_P8,OUT2_P8,R09
                      ; OUT0_P8=0.017578125*OUT2_P8
        150 40515D ADD OUT0_P8,OUT2_P8,R11
                     ; OUT0_P8=0.018066406*OUT2_P8
        151 0151FB SUB OUT0_P8,OUT2_P8,R00,CVT0
                      ; OUT0_P8=-0.98193359*OUT2_P8
        152 48F19A SUB OUT0_P8,OUT1_P8,R05
                      ; OUT0_P8=-0.031250000*OUT1_P8-0.98193359*OUT2_P8
        153 48F1DA SUB OUT0_P8,OUT1_P8,R07
                      ; OUT0_P8=-0.039062500*OUT1_P8-0.98193359*OUT2_P8
        154 4032FE LDA PHSIG,DAR,R08     ;PHSIG = IN PHASE INPUT
        155 48F1DD ADD OUT0_P8,OUT1_P8,L01
                      ; OUT0_P8=1.9609375*OUT1_P8-0.98193359*OUT2_P8
        156 42F91D ADD OUT0_P8,OUT0_P7,R09
                      ; OUT0_P8=1.9609375*OUT1_P8-0.98193359*OUT2_P8+1*IN0_P8
                   ;**************************************************************
                   ;
                   ;START OF 90 HZ QUADRATURE PEAK DETECTOR
                   ;
        157 4AE4EF LDA DAR,PKQD90,R00     ;DAR = OLD PEAK
        158 406CAB SUB DAR,NEW90,L02      ;DAR = OLD - NEW
        159 7479AF LDA PKQD90,NEW90,L02,CNDS ;PKQD90=NEW90 IF NEW90>PKQD90
                   ;END OF 90 HZ QUADRATURE PEAK DETECTOR
                   ;**************************************************************
                   ;
                   ;CODE FOR ZERO 1 FOR 150HZ BPF
                   ;
        160 4CF9FF LDA QD150,OUT0_P8,R00
                      ; OUT0_Z4=1*IN0_Z4
        161 4CF1FB SUB QD150,OUT1_P8,R00     ;QD150 = 150 HZ FILTERED QUADRATURE
                      ; OUT0_Z4=-1.00000000*IN1_Z4+1.00000000*IN0_Z4
                   ;END OF 150HZ BPF
                   ;
        162 4AA9A7 ABS NEW150,QD150,L02
        163 40816A SUB NEW150,NEW150,R04
        164 40812A SUB NEW150,NEW150,R02 ;NEW150=\150 HZ FILTERED QUADRATURE\/4
                   ;**************************************************************
                   ;
                   ;START OF 150 HZ QUADRATURE PEAK DETECTOR
                   ;
        165 4046EF LDA DAR,PKQD150,R00      ;DAR = OLD PEAK
        166 40C4AB SUB DAR,NEW150,L02       ;DAR = OLD - NEW
        167 7084AF LDA PKQD150,NEW150,L02,CNDS ;PKQD150=NEW150 IF NEW150>PKQD150
                   ;END OF 150 HZ QUADRATURE PEAK DETECTOR
```

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ISIS-II 2920 ASSEMBLER V1.0                                         PAGE  10
VECTOR FAR FIELD MONITOR -- 2920 #1    APR 1, 1982
  LINE  LOC OBJECT SOURCE STATEMENT
   413              ;*************************************************************
   414  168 404EEF LDA DAR,SUM
   415  169 4206DF LDA SUM,ENVQD90,L01
   416  170 420EDD ADD SUM,ENVQD150,L01        ;SUM = (QUAD SUM)
   417  171 400E7C ADD SUM,SUM,R4
   418  172 46000E LDA QOFF,QOFF,R01           ;CONVERT OFFSET TO A MOSTLY POS. #
   419  173 968AED ADD QOFF,KP3,OUT1
   420  174 92041A SUB SUM,QOFF,R01,OUT1       ;ADD IN EXTERNAL OFFSET
   421  175 9000EF OUT1
   422  176 9000EF OUT1
   423  177 4000EF NOP
   424  178 4000EF NOP
   425  179 4000EF NOP
   426              ;*************************************************************
   427              ;
   428              ;START OF ALL 4 ENVELOPE DETECTORS AND COUNTER
   429              ;SAMPLES AT 116 HZ RATE (EVERY 56 PROGRAM PASSES)
   430              ;
   431  180 4846EF LDA DAR,COUNT,R00
   432  181 7099EF LDA ENVIN90,PKIN90,R00,CNDS     ;RESET ENVELOPE OUTPUTS
   433  182 7681FF LDA ENVIN150,PKIN150,R00,CNDS   ;          "
   434  183 7EA4EF LDA ENVQD90,PKQD90,R00,CNDS     ;          "
   435  184 7406FF LDA ENVQD150,PKQD150,R00,CNDS   ;          "
   436  185 7083FF LDA PKIN90,KP0,R00,CNDS         ;RESET PEAK OUTPUTS TO 0
   437  186 7483EF LDA PKIN150,KP0,R00,CNDS        ;          "
   438  187 74D3EF LDA PKQD90,KP0,R00,CNDS         ;          "
   439  188 5ABE4C ADD COUNT,KM1,R03,EOP           ;COUNT = COUNT - 1/64
   440  189 7086EF LDA PKQD150,KP0,R00,CNDS        ;          "
   441  190 7A9EEF LDA COUNT,KP7,CNDS              ;RESET COUNTER
   442  191 4000EF NOP
   443              END

SYMBOL:                         VALUE:

OUT2_P2                            0
OUT2_P1                            0
OUT2_P3                            0
OUT2_P4                            0
OUT2_P5                            0
OUT2_P6                            0
OUT2_P7                            0
OUT2_P8                            0
OUT1_P9                            0
OUT1_P10                           0
OUT1_P11                           0
```

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ISIS-II 2920 ASSEMBLER V1.0                                   PAGE  11

VECTOR FAR FIELD MONITOR -- 2920 #1     APR 1, 1982

OUT1_P12                         0
CMP                              1
GOFF                             2
OUT1_P1                          3
OUT0_P1                          4
PHSIG                            5
OUT1_P2                          6
OUT0_P2                          7
IN90                             8
NEW90                            9
OUT1_P3                         10
OUT0_P3                         11
OUT1_P4                         12
OUT0_P4                         13
IN150                           14
GDSIG                           15
NEW150                          16
PKIN90                          17
PKIN150                         18
ENVIN150                        19
ENVIN90                         20
OUT1_P5                         21
OUT0_P5                         22
OUT1_P6                         23
OUT0_P6                         24
GD90                            25
OUT1_P7                         26
OUT0_P7                         27
OUT1_P8                         28
OUT0_P8                         29
PKGD90                          30
GD150                           31
PKGD150                         32
SUM                             33
ENVGD90                         34
ENVGD150                        35
COUNT                           36

ASSEMBLY COMPLETE
ERRORS     =    0
WARNINGS   =    0
RAMSIZE    =   37
ROMSIZE    =  192
```

```
2920 ASSEMBLER
... INFORMED BY ... 2920 ...
VECTOR FAR FIELD MONITOR - 2920 #...
LOC  OBJECT  SOURCE STATEMENT

                $    TITLE ... FAR FIELD ... 2920 #2    10  17  1-82 )
                $    DATE ...
                $    PAGELENGTH ...
                ;******************************************************************
                ;
                ;         2920 ASSEMBLER LANGUAGE PROGRAM FOR CALCULATING
                ;         THE SQUARE ROOT OF THE SUM OF THE SQUARES OF TWO
                ;         INPUT SIGNALS.  THIS PROGRAM IS THE SECOND PART OF THE
                ;         SIGNAL PROCESSING FUNCTION FOR THE VECTOR FAR FIELD
                ;         MONITOR.  IT RESIDES IN ... #2
                ;
                ;
                ;******************************************************************
                ;
                ;         THE PROGRAM ACCEPTS TWO INPUT SIGNALS ON INO AND IN1
                ;         THEY ARE SQUARED, SUMMED, AND THE SQUARE ROOT OF THE SUM
                ;         IS OUTPUT ON OUT1
                ;
                ;******************************************************************
                ;
                ;           INO  = SUM INPUT
                ;           IN1  = DIFF INPUT
                ;           OUT1 = DDM OUTPUT
                ;
  0 0066EB  SUB DAR   DAR,   RO   INO              INPUT SUM SIGNAL
  1 0000EF  INO
  2 0000EF  INO
  3 0000EF  INO
  4 0000EF  INO
  5 0000EF  INO
  6 4000EF  NOP
  7 4000EF  NOP
  8 6000EF  CVTS
  9 FRE6ED  ADD DAR,  KM2,   RO,  CND6
 10 4000EF  NOP
 11 4000EF  NOP
 12 7100EF  CVT7
 13 4000EF  NOP
 14 4000EF  NOP
 15 6100EF  CVT6
 16 4000EF  NOP
 17 4000EF  NOP
 18 5100EF  CVT5
 19 4000EF  NOP
```

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 ... ASSEMBLER ...                                               PAGE  2
 ... FAR FIELD MONITOR -- 2920 #2   MAR 19  1982
  LINE  LOC OBJECT SOURCE STATEMENT

   45    20 4000EF NOP
   46    21 4100EF CVT4
   47    22 4000EF NOP
   48    23 4000EF NOP
   49    24 3100EF CVT3
   50    25 4000EF NOP
   51    26 4000EF NOP
   52    27 2100EF CVT2
   53    28 4000EF NOP
   54    29 4000EF NOP
   55    30 1100EF CVT1
   56    31 4000EF NOP
   57    32 4000EF NOP
   58    33 0100EF CVT0
   59    34 4000EF NOP
   60    35 4000EF NOP
   61    36 4022EF LDA SUM, DAR,  RO                  ;SAVE SUM
   62    37 1066E5 SUB DAR, DAR,  RO, IN1             ;INPUT DIFF SIGNAL
   63    38 1000EF IN1
   64    39 1000EF IN1
   65    40 1000EF IN1
   66    41 1000EF IN1
   67    42 1000EF IN1
   68    43 4000EF NOP
   69    44 4000EF NOP
   70    45 6000EF CVT5
   71    46 EBE6ED ADD DAR, KM2,  RO, CND6
   72    47 4000EF NOP
   73    48 4000EF NOP
   74    49 7100EF CVT7
   75    50 4000EF NOP
   76    51 4000EF NOP
   77    52 6100EF CVT6
   78    53 4000EF NOP
   79    54 4000EF NOP
   80    55 5100EF CVT5
   81    56 4000EF NOP
   82    57 4000EF NOP
   83    58 4100EF CVT4
   84    59 4000EF NOP
   85    60 4000EF NOP
   86    61 3100EF CVT3
   87    62 4000EF NOP
   88    63 4000EF NOP
   89    64 2100EF CVT2
   90    65 4000EF NOP
```

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ISIS-II 2920 ASSEMBLER V1.0                                        PAGE    3
VECTOR PAR FIELD MONITOR -- 2920 #2   MAR 19, 1982
 LINE  LOC OBJECT SOURCE STATEMENT

  66 4000EF NOP
  67 1100EF CVT1
  68 4000EF NOP
  69 4000EF NOP
  70 0100EF CVT0
  71 4000EF NOP
  72 4000EF NOP
  73 4022FF LDA DIF, DAR,  RO             ;SAVE DIF
            ;**************************************************************
            ;
            ;       SQUARE OF QUADRATURE SUM OF 90 HZ AND 150 HZ COMPONENTS
            ;
  74 4000E7 ABS SUM , SUM
  75 4600EB SUB QDSQ,QDSQ,  R00
  76 404EEF LDA  DAR, SUM,  R00
  77 F5000C ADD QDSQ,  SUM,  R01,CND7
  78 E5002C ADD QDSQ,  SUM,  R02,CND6
  79 D5004C ADD QDSQ,  SUM,  R03,CND5
  80 C5006C ADD QDSQ,  SUM,  R04,CND4
  81 B5008C ADD QDSQ,  SUM,  R05,CND3
  82 A500AC ADD QDSQ,  SUM,  R06,CND2
  83 9500CC ADD QDSQ,  SUM,  R07,CND1
  84 8500EC ADD QDSQ,  SUM,  R08,CND0            ,QDSQ = SUM**2
            ;**************************************************************
            ;
            ;SQUARE OF IN-PHASE DIFFERENCE OF 90 HZ AND 150 HZ COMPONENTS
            ;
  85 4008F7 ABS DIF , DIF
  86 4608FB SUB INSQ,INSQ,  R00
  87 404CEF LDA DAR , DIF,  R00
  88 F5081C ADD INSQ,  DIF,  R01,CND7
  89 E5083C ADD INSQ,  DIF,  R02,CND6
  90 D5085C ADD INSQ,  DIF,  R03,CND5
  91 C5087C ADD INSQ,  DIF,  R04,CND4
  92 B5089C ADD INSQ,  DIF,  R05,CND3
  93 A508BC ADD INSQ,  DIF,  R06,CND2
  94 9508DC ADD INSQ,  DIF,  R07,CND1
  95 8508FC ADD INSQ,  DIF,  R08,CND0               ;INSQ = DIF**2
            ;***************************************************************
            ;
            ;      COMPUTE SUM OF SQUARES
            ;
  96 4608ED ADD QDSQ,INSQ,R00        ,QDSQ = SUM**2 + DIF**2
            ;**************************************************************
            ;
```

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?CTOR FAR FIELD MONITOR -- 2920 #2   MAR 19, 1982

 LINE  LOC OBJECT SOURCE STATEMENT

  137                ;START OF SQRT OF QDSQ
  138                ;
  139    97 4210EF LDA  TEMP QDSQ
  140    98 4244EF LDA    DAR,    QDSQ          ; SCALE INPUT UP BY A POWER OF 4
  141    97 4066CB SUB    DAR,   DAR, LO1       ; SO THAT IT WILL LIE IN THE
  142   100 4066C3 AND    DAR,   DAR, LO1       ; RANGE OF 0.25 TO 1.0
  143   101 406622 AND    DAR,   DAR, RO2
  144   102 406622 AND    DAR,   DAR, RO2
  145   103 406622 AND    DAR,   DAR, RO2
  146   104 F910AF LDA  TEMP,  TEMP, LO2, CND7
  147   105 D910AF LDA  TEMP,  TEMP, LO2, CND5
  148   106 B910AF LDA  TEMP,  TEMP, LO2, CND3
  149   107 9910AF LDA  TEMP,  TEMP, LO2, CND1
  150   108 48101E LDA     DDM,  TEMP, RO1       ; DO A PIECEWISE LINEAR
  151   109 48107C ADD     DDM,  TEMP, RO4       ; APPROXIMATION TO SQRT
  152   110 48109C ADD     DDM,  TEMP, RO5       ; IN THIS RANGE.
  153   111 4810FA SUB     DDM,  TEMP, RO8
  154   112 4810CF LDA  TEMP,  TEMP, LO1
  155   113 48105C ADD     DDM,  TEMP, RO3
  156   114 48101B SUB     DDM,  TEMP, RO9
  157   115 4810CF LDA  TEMP,  TEMP, LO1
  158   116 48103C ADD     DDM,  TEMP, RO2
  159   117 48109C ADD     DDM,  TEMP, RO5
  160   118 4810BC ADD     DDM,  TEMP, RO6
  161   119 48101B SUB     DDM,  TEMP, RO9
  162   120 F9181E LDA     DDM,     DDM, RO1, CND7     ; SCALE OUTPUT DOWN
  163   121 D9181E LDA     DDM,     DDM, RO1, CND5     ; BY THE APPROPRIATE
  164   122 B9181E LDA     DDM,     DDM, RO1, CND3     ; POWER OF 2.
  165   123 99181E LDA     DDM,     DDM, RO1, CND1
  166                ;************************************************************
  167                ;                  SCALE DDM OUTPUT TO BE BIPOLAR
  168                ;
  169   124 40BA1C ADD DDM,KM7,RO1        ;DDM = DDM - 7/16
  170   125 484CEF LDA DAR,DDM
  171   126 484C2C ADD DAR,DDM,RO2
  172   127 484C0C ADD DAR,DDM,RO1        ;DAR = (DDM - 3/8) * 1.75
  173                ; OUPUT RANGE IS -.75 TO +1.0 VOLTS
  174                ;************************************************************
  175   128 4000EF NOP
  176   129 4000EF NOP
  177   130 4000EF NOP
  178   131 4000EF NOP
  179   132 9000EF OUT1                   ;OUTPUT DDM
  180   133 9000EF OUT1
  181   134 9000EF OUT1
  182   135 9000EF OUT1
```

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VECTOR FAR FIELD MONITOR -- 2920 #2   MAR 19, 1982
  LINE  LOC OBJECT SOURCE STATEMENT

   183  136 9000EF OUT1
   184  137 4000EF NOP
   185  138 4000EF NOP
   186  139 4000EF NOP
   187  140 4000EF NOP
   188  141 4000EF NOP
   189  142 4000EF NOP
   190  143 4000EF NOP
   191  144 404CEF LDA DAR,DIF
   192  145 4000EF NOP
   193  146 4000EF NOP
   194  147 4000EF NOP
   195  148 A000EF OUT2
   196  149 A000EF OUT2
   197  150 A000EF OUT2
   198  151 A000EF OUT2
   199  152 A000EF OUT2
   200  153 4000EF NOP
   201  154 4000EF NOP
   202  155 4000EF NOP
   203  156 4000EF NOP
   204  157 4044EF LDA DAR,SUM
   205  158 4000EF NOP
   206  159 4000EF NOP
   207  160 4000EF NOP
   208  161 4000EF NOP
   209  162 B000EF OUT3
   210  163 B000EF OUT3
   211  164 B000EF OUT3
   212  165 B000EF OUT3
   213  166 B000EF OUT3
   214  167 4000EF NOP
   215  168 4000EF NOP
   216  169 4000EF NOP
   217  170 4000EF NOP
   218  171 4000EF NOP
   219  172 4000EF NOP
   220  173 4000EF NOP
   221  174 4000EF NOP
   222  175 4000EF NOP
   223  176 4000EF NOP
   224  177 4000EF NOP
   225  178 4000EF NOP
   226  179 4000EF NOP
   227  180 4000EF NOP
   228  181 4000EF NOP
```

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[illegible] ASSEMBLER V1 [illegible]                                PAGE   [illegible]
VECTOR FAR FIELD MONITOR -- 2920 #2   MAR 19, 1982
  LINE  LOC OBJECT SOURCE STATEMENT

   229   182 4000EF NOP
   230   183 4000EF NOP
   231   184 4000EF NOP
   232   185 4000EF NOP
   233   186 4000EF NOP
   234   187 4000EF NOP
   235   188 5000EF EOP
   236   189 4000EF NOP
   237   190 4000EF NOP
   238   191 4000EF NOP
   239                END

SYMBOL                              VALUE:

SUM                                      0
DIF                                      1
[illegible]OSQ                           2
[illegible]NSQ                           3
TEMP                                     4
[illegible]OM                            5

ASSEMBLY COMPLETE
ERRORS      =     0
WARNINGS    =     0
RAMSIZE     =     6
ROMSIZE     =   192
```